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CABBAGE

..... factors affecting vitamin values and palatability

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Agricultural Experiment Stations of ALABAMA, COLORADO, GEORGIA, INDIANA, ILLINOIS, KANSAS, LOUISIANA, MAINE, MICHIGAN, MINNESOTA, MISSISSIPPI, NEW YORK CORNELL, NORTH CAROLINA, OHIO, OKLAHOMA, OREGON, RHODE ISLAND, TENNESSEE, TEXAS, UTAH AND THE UNITED STATES REGIONAL VEGETABLE BREEDING LABORATORY, CHARLESTON, SOUTH CAROLINA, cooperating.

Foreword

The cabbage plant traveled far before arriving in the American States in which these recent studies were conducted. Originating probably in Asia Minor, like its relatives kale and collards, cabbage was known to the Greeks and Romans. It was carried westward by the Celts before the time of the Romans, and presently became a familiar and favored article of food in central and northwestern Europe. Its name "cabbage" appears to have been derived from the French word for head, "caboche", which aptly describes its structure. It was brought to America by Jacques Cartier in 1541-42, and doubtless found its way promptly into what is now the United States before the first written records of 1669.

In recent times added interest has been attracted to this familiar vegetable in consequence of the identification of the nature and function of certain essential vitamins and other nutrient principles, and the development of quantitative methods for their estimation. As the program of research unfolded under the National Cooperative Project on the Conservation of the Nutritive Value of Foods, it appeared appropriate to include certain studies of cabbage in that program. The cooperative aspects of such a study were not the least significant, since that involved the joint activities of numerous State agricultural experiment stations and Federal agencies. Thus the influence of the environment in which the plants were grown could be appraised, and the skills and knowledge of several investigators would be brought to bear upon the planning and conduct of the researches.

Presently a score or more of such stations became involved in the project. This resulted in the accumulation of many and diverse data pertinent to a more intelligent understanding of the composition and nutrient values of cabbage, and the effects of various methods of preparation for human consumption. These data have been assembled, analyzed, and presented in an orderly pattern in this bulletin, together with a discussion of their significance and application.

Acknowledgment is made to Dr. C. H. Bailey, Regional Coordinator of the North Central Region of the National Cooperative Project on the Conservation of the Nutritive Value of Food, for the preparation of the Foreword and to Dr. W. E. Krauss, Associate Director of the Ohio Agricultural Experiment Station, for help in processing this bulletin. Special thanks are expressed to Dr. Faith Fenton, Dr. Ethelwyn Wilcox, and Dr. Jessie Whitacre as members of the editorial committee for reviewing the bulletin and offering their suggestions and criticisms.

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CABBAGE

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PART I. COMPILATION OF NATIONAL COOPERATIVE RESEARCH FINDINGS ON CABBAGE

INTRODUCTION

The organization and purposes of the National Cooperative Project, Conservation of the Nutritive Value of Foods, have been reviewed by Leichsenring and coauthors (12) in the first of a series of commodity bulletins to be published from data collected under this project. The present bulletin is the second of this series and deals with the commodity cabbage.

The contributions were made by 20 agricultural experiment stations and the United States Regional Vegetable Breeding Laboratory, Charleston, South Carolina,[1] and deal principally with ascorbic acid. A few studies were made on the thiamine, riboflavin, niacin, pantothenic acid, and carotene content. Among the variables studied in relation to their effect on the composition of raw cabbage were: variety, season, maturity, length of storage, and storage temperature; of cooked cabbage: the type of cooking utensil used, the amount cooked at one time, the amount of water used for boiling, the size of pieces used, and the length of cooking time. The palatability of cooked cabbage was studied at four stations. Methods of cooking and length of holding periods were considered.

This bulletin is presented in two parts, the first of which is a compilation of the contributions from workers at these 21 stations; the second, a review of other research findings on cabbage. In general, the data in Part I are presented in the units in which they were reported by the workers but have been rearranged in order to make comparisons and facilitate presentations. For instance, the fundamental data from several stations may have contained information on raw and cooked

[1]This laboratory will be referred to hereafter as the Charleston Laboratory and in cases of enumeration will be included with the agricultural experiment stations.

cabbage, on several varieties, and on the same variety grown in two or more seasons. In cases such as these, the data were rearranged in order to show the effects of cooking, variety, and season. Details are presented in so far as they tend to clarify the data. In instances where data have been published, they are reviewed in this bulletin and reference is made to the published report.

The multiplicity of variables has contributed to the complexity of summarizing the data. In the tables and discussion all data are recorded. Certain relationships that became apparent with the compilation of these diverse and comprehensive data are presented. Statistical analyses were made by the contributors in some instances and are presented herein, but further analyses of similar data from several stations did not seem justified.

ASCORBIC ACID IN RAW CABBAGE

VARIETY

Contributions from Cornell, Illinois, Kansas, Maine, Minnesota, Ohio, Oregon, Rhode Island, Texas, Utah stations and the Charleston Laboratory. The relation of variety or strain of cabbage to ascorbic acid content was investigated at these 11 stations and the data are reported in table 1. Average values ranged from 27.0 to 100.74 mg per 100 gm fresh weight for the 38 varieties and strains reported.

Values of 50 mg or higher were reported for a number of varieties in several locations. The Rhode Island station (25) reported a value of 58.8 mg for Late Glory of Enkhuizen, 58.2 for Wisconsin All Season, and 56.4 for Savoy. Ohio (13, 20, 21) obtained values of 62 mg for the All Season variety, 57 for Marion Market, and 56 for Copenhagen Market. Maine (5) reported a value of 70.58 mg for Wisconsin No. 8 Ballhead and 100.74 for Mammoth Rock Red. Analyses of Round Red Dutch at the Oregon station (10) showed a value of 56 mg.

Two experimental strains of cabbage grown at the Charleston Laboratory (22) and harvested in February, 1943 were found to be richer in ascorbic acid than the commercial varieties in Rhode Island and Ohio. One strain designated as Volga-2 contained an average of 66.7 mg and the other, Charles Wakefield-1, averaged 62.1 mg. Both strains, however, had lower values, 53.2 and 40.5 mg, respectively, when grown the following season and harvested in June, 1943.

The two highest average figures, 75 and 100.74 mg, were reported by the Ohio (21) and Maine stations (5), respectively, for red cabbage.

TABLE 1.—Ascorbic acid content of different varieties and strains of freshly harvested cabbage

Variety or strain	Station contributing	Time of harvest	Basis for figures	Ascorbic acid		Moisture	Reference number
				ave.	range		
				Mg/100 gm.		Percent	
All Head Faultless	Kansas	7-26-44	3 samples each of 2 heads	44.4	37.9–49.8	93.3	2
	Kansas	7-28-44	3 samples each of 2 heads	41.8	36.4–49.2	92.8	2
All Season	Kansas	7-18-44	3 samples each of 2 heads	53.2	50.1–58.5	93.0	2
	Kansas	7-28-44	3 samples each of 2 heads	48.8	44.2–53.4	93.3	2
	Kansas	8-1-44	3 samples each of 2 heads	48.2	42.6–54.4	92.8	2
	Ohio	Summer 1943	6 heads in duplicate	51	———	———	21
	Ohio	Summer 1943	10 heads in duplicate	62	———	———	13
Bugner	Kansas	8-10-44	3 samples each of 2 heads	59.5	58.6–60.7	92.0	2
	Minnesota	1945	1 gathering (4 lots)	58.4*	51.2–65.5	91.3*	16
Charleston Wakefield	U.S.D.A.	Feb. 1943	Average 6 samples	40.9	———	———	22
	U.S.D.A.	June 1943	Average 2 samples (13 heads)	37.8	———	———	22
	Texas	June 1945	Average 4 samples, 3 dates (4 heads)	54.8*	49.5–61.9	———	31
	Texas	Jan.-Mar. 1946	Average 4 samples, 4 dates (4 heads)	42.9*	34.9–47.9	———	31
Charleston Wakefield–1	U.S.D.A.	Jan. 5, 1943	2 samples each of 2 heads at 3 harvesting dates	62.1	———	———	22
	U.S.D.A.	June 1943	Average 2 samples (15 heads)	40.5	———	———	22
Copenhagen Market	Kansas	7-13-44	3 samples each of 2 heads	51.6	46.2–55.7	94.0	2
	Ohio	Summer 1943	9 heads in duplicate	56	———	———	21
	Rhode Island	7-18 and 7-25-44	Composite of 5 heads	46.8*	41.6–52.1	———	25
	U.S.D.A.	Feb. 1943	Average 6 samples	39.3	———	———	22
	U.S.D.A.	June 1943	Average 2 samples (11 heads)	33.4	———	———	22

TABLE 1.—Ascorbic acid content of different varieties and strains of freshly harvested cabbage—continued

Danish	Cornell	Oct. 1944	95 samples		32 –59	———	34
Danish Ball	Oregon	-		43	———	———	9
Danish Ballhead	Minnesota	1942	1 gathering (2 lots)	44.9*	42.2–47.6	———	19
	Minnesota	1943	4 gatherings (4 lots)	46.9*	41.7–54.8	———	19
	Minnesota	Summer 1944	2 gatherings (4 lots)	41.8*	40.3–43.2	92.2*	16
	Utah	Sept. 1945	6 heads	50.4	———	———	33
Daybreak	Kansas	6-28-44	3 samples each of 2 heads	68.3	63.5–72.7	92.4	2
De Lux	Kansas	7-20-44	3 samples each of 2 heads	45.7	42.0–48.9	93.3	2
Drumhead Savoy	Maine	Summer 1945	2 tests	43.59	———	———	5
Early Glory of Enkhuizen	Rhode Island	7-18-44	Composite of 5 heads	47.7	———	———	25
Early Jersey Wakefield	Rhode Island	7-18 and 7-25-44	Composite of 5 heads	40.8*	39.4–42.3	———	25
Early Marvel	Kansas	7-18-44	3 samples each of 2 heads	51.4	47.9–53.1	93.5	2
Flat Dutch	Ohio	Summer 1943	9 heads in duplicate	45	———	———	21
Glory of Enkhuizen	Texas	Jan., Feb , March 1946	Average 4 samples, 4 dates (4 heads)	41 4*	29.6–49.4	93.2	31
Golden Acre	Kansas	6-28-44	3 samples each of 2 heads	58.2	53.6–62.8	92.4	2
	Minnesota	Summer 1944	2 gatherings (4 lots)	32.4*	30.3–34.5	93.9*	16
	Ohio	July 1943	10 heads in duplicate	53	———	———	14
	Ohio	October 1943	3 heads in duplicate	58	———	———	14
	Rhode Island	7-18-44	Composite of 5 heads	37 5	———	———	25
Green Acre	Kansas	6-28-44	3 samples each of 2 heads	64 5	59 0–70 2	92 1	2
Late Glory of Enkhuizen	Rhode Island	7-18 and 7-25-44	Composite of 5 heads	49 8*	40 7–58 8	———	25

TABLE 1.—Ascorbic acid content of different varieties and strains of freshly harvested cabbage—continued

Mammoth Rock Red	Maine	Summer 1945	2 tests	100.74	———	——— 5
Marion Market	Kansas	7-13-44	3 samples each of 2 heads	54.5	51.2–58.7	92.8 2
	Minnesota	1942	2 gatherings (4 lots)	40.4*	37.8–44.2	——— 19
	Minnesota	1943	4 gatherings (7 lots)	36.2*	28 5–44.2	——— 19
	Minnesota	Summer 1944	2 gatherings (4 lots)	36.4*	30.6–39.1	92.8* 16
	Minnesota	1945	1 gathering (4 lots)	52.2*	52.1–52.3	92.2* 16
	Ohio	1944	9 heads (3 heads composited on 3 occasions)	52.2	———	——— 20
	Ohio	1944	19 heads (10 in duplicate 3 comp. of 3)	57	———	——— 20
	Rhode Island	7-18-44	Composite of 5 heads	43.5	———	——— 25
	U.S.D.A.	Feb. 1943	Average 6 samples	49.1	———	——— 22
	U.S.D.A.	June 1943	Average 2 samples (12 heads)	40.6	———	——— 22
Racine Market	Illinois	10-8-42	6 determinations	47 †	47 –49 †	92.6 ± 0.1 28
	Illinois	10-4-43	6 determinations	43 †	42 –45 †	93.2 ± 0 3 28
	Illinois	10-25-43‡	6 determinations	47 †	45 –48 †	92.4 ± 0.0 28
	Kansas	7-18-44	3 samples each of 2 heads	51.2	49 9–55.1	94.0 2
Red Cabbage	Ohio	Summer 1943	6 heads in duplicate	75	———	——— 21
Resistant Detroit	Illinois	10-8-42	6 determinations	48 †	46 –49 †	92.6 ± 0 1 28
	Illinois	9-30-43	6 determinations	41 †	40 –43 †	92.9 ± 0 1 28
	Illinois	10-25-43	5 determinations	45 †	44 –45 †	92.8 ± 0.1 28
	Kansas	7-18-44	3 samples each of 2 heads	47.4	44.4–51.6	93.3 2
	Kansas	7-26-44	3 samples each of 2 heads	48.3	47.0–49.6	92.8 2
	Minnesota	1945	1 gathering (4 lots)	47.0*	45.6–48.5	93.1* 18
Round Red Dutch	Oregon	12-30-42		56	———	——— 10
Round Head No. 18	U.S.D.A.	1-2-43 1-5-43	2 samples each of 2 heads each of 3 harvesting dates	45.6	———	——— 22
	U.S.D.A.	Feb. 1943	Average 6 samples	42.5	———	——— 22
	U.S.D.A.	June 1943	Average 2 samples (11 heads)	33.5	———	——— 22

TABLE 1.—Ascorbic acid content of different varieties and strains of freshly harvested cabbage—concluded

Savoy	Oregon			27.0	———	———	10
	Ohio	Summer 1943	6 heads in duplicate	53	———	———	21
	Rhode Island	7-25-44	Composite of 5 heads	56.4	———	———	25
Stone	Oregon			33	———	———	10
Vaughn All Season	Kansas	8-1-44	3 samples each of 2 heads	47.2	46.1–48.6	92.5	2
Volga–1	U.S.D.A.	Feb. 1943	Average 6 samples	43.1	———	———	22
	U.S.D.A.	June 1943	Average 2 samples (13 heads)	46.8	———	———	22
Volga–2	U.S.D.A.	12-30-42 1-2-43, 1-5-43	2 samples each of 2 heads each of 3 harvesting dates	66.7	———	———	22
	U.S.D.A.	June 1943	Average 2 samples (6 heads)	53.2	———	———	22
Wisconsin All Season	Rhode Island	7-19-44	Composite of 5 heads	58.2	———	———	25
Wisconsin #8 Ballhead	Maine	Summer 1946	2 tests	70.58	———	———	5
Wisconsin Ballhead	Kansas	7-28-44	3 samples each of 2 heads	45.4	41.6–49.6	93.3	2
	Kansas	8-1-44	3 samples each of 2 heads	49.6	42.3–56.9	92.5	2
Wisconsin Golden Acre	Illinois	10-8-42	6 determinations	42 †	40 –46 †	92.7 ± 0.3	28
Wisconsin Hollander	Kansas	8-1-44	3 samples each of 2 heads	46.0	42.6–49.6	92.5	2
Wisconsin Pride	Kansas	7-18-44	3 samples each of 2 heads	52.7	49.1–56.0	93.3	2
	Kansas	7-20-44	3 samples each of 2 heads	48.6	44.6–51.7	94.0	2

*Calculated average.

†Figures transcribed from milligrams per gram to milligrams per 100 grams.

‡Stored in refrigerator overnight and determinations made 10-26-43.

The range of ascorbic acid values in cabbage varied from the higher values indicated above to a low of approximately 30 mg fresh basis. Golden Acre variety grown at the Minnesota station (16) in the summer of 1944 contained an average of 32.4 mg for the four lots tested. Similar values were found for two varieties grown at the Charleston Laboratory in 1943 (22): Copenhagen Market, 33.4 mg and Round Head No. 18, 33.5 mg. Oregon (10) reported two varieties with values in this lower range: Stone, 33 mg and Savoy, 27 mg.

Illinois (28) reported on three varieties, Racine Market, Resistant Detroit, and Wisconsin Golden Acre, with average values of 47, 48, and 42 mg, respectively, which are intermediate among the high and low values cited above.

The stability of vitamin C in different varieties of cabbage when the vegetable was subjected to treatment, such as storage, cooking, and dehydration, was studied at the Charleston Laboratory. Differences due to variety were observed at the Minnesota station in a study of the effect of various cooking methods. The relationships of these factors to variety are discussed in the sections devoted to these topics.

SEASONS

Contributions from Colorado, Illinois, Minnesota, Tennessee, Texas stations and the Charleston Laboratory. The question has been asked whether or not there is a variation in the concentration of ascorbic acid in the same variety of cabbage when grown in two different seasons. This was investigated at the Charleston Laboratory (22) for five cabbage strains grown in succeeding seasons of the same year. In four of the five strains the vitamin C concentration was higher in the cabbage from the February harvest than from the same variety at the June harvest (table 2), but in only three cases were the differences significant. The average seasonal difference for the five strains was also significant.

Texas (31) reported average values for Charleston Wakefield in a spring crop to be 54.8 mg and in a fall crop, 42.9 mg. The difference between seasons is greater than any found by the Charleston Laboratory, and is in the opposite direction.

In some locations the duration of the growing season either does not permit the production of two crops or it is not the practice to plant the same variety at two different seasons in the same year. The Minnesota (16, 19) and Illinois stations (28) reported ascorbic acid values obtained in successive years on certain varieties. Variations from year to year were evident. Ascorbic acid values for four varieties (Marion

TABLE 2.—Ascorbic acid content* of raw cabbage in different seasons of the same year as reported by the Charleston Laboratory† (fresh weight)

Variety or strain	Ascorbic Acid		
	February‡	June‡	Seasonal difference
	Milligrams per 100 grams		
Copenhagen Market	39.3	33.4	5 9§
Round Head No. 18	42 5	33.5	9.0§
Marion Market	49.1	40.6	8.5§
Volga-1	43.1	46 8	3.7
Charleston Wakefield	40.9	37.8	3 1
Average	43 0	38.4	5.6§

*Modification of Morell method of analysis used.

†Proc. Am. Soc. Hort. Sci. 45:396-404.

‡Each figure for February data represents an average of six samples whereas each figure for June represents an average of two samples.

§Significant at 5 percent level.

Market, Danish Ballhead, Racine Market, and Resistant Detroit) tested in successive years at the two stations are shown in table 3.

The ascorbic acid content of cabbage purchased at different seasons was reported in the quantity cookery studies at the Colorado and Tennessee stations. The variety and previous history of the vegetable were not known in either case. At Colorado (23) the findings were reported for four successive periods of thirty days each in the fall, winter, and spring of 1943-44. The average ascorbic acid values in the

TABLE 3.—Variations in the ascorbic acid content of raw cabbage in different years (fresh weight)

Year	Ascorbic Acid				
	Minnesota		Illinois		
	Marion Market	Danish Ballhead	Racine Market	Resistant Detroit	Reference Number
	Milligrams per 100 grams				
1942	40.4	44 9	47	48	19, 28
1943	36 2	46.9	43*	41*	19, 28
1944	36.4	41.8	—	—	16
1945	52.2	——	—	—	16

*Figures for harvest date nearest that in 1942.

different periods varied from 53.7 in Period I, fall, to 25.0 mg per 100 gm in Period IV, spring, and the differences were found to be significant at the 1 percent level.

At the Tennessee station (8), samples of spring cabbage purchased during March, April, and May 1944, were found to have a higher average concentration of vitamin C than winter cabbage purchased in the months of November and December of the preceding year. On a dry basis, the spring cabbage had an average of 598.5 ± 28.17 mg per 100 gm as compared to 408 ± 18.4 for winter cabbage.

The foregoing studies do not give the final answer as to seasonal differences. No study has a replication of seasonal values. Tennessee (8) and Texas (31) are in agreement in that spring values were higher than winter, while for the Charleston Laboratory (22) and the Colorado station (23) the reverse is true.

MATURITY

Contributions from Kansas and Texas stations. The Kansas station (2) tested 21 varieties for the effect of the maturity of cabbage on its ascorbic acid content. These workers found that cabbage had the highest ascorbic acid values at the immature stage. The average figures obtained for the three stages of maturity studied were: immature, 58.1 mg; mature, 49.9; past maturity, 48.3. Only two varieties were tested at all three stages of maturity.

Content of ascorbic acid in Charleston Wakefield variety grown at Texas station (31) ranged from 47.9 to 43.0 mg for three harvestings from January 21 to February 12. The content on March 7 dropped to 34.9 mg. Glory of Enkhuizen harvested one day later than Wakefield had values of 49.4, 41.8, and 44.9 mg followed by a content of 29.6 mg on March 8. With the latter variety, values 4 days earlier and 3, 5, and 7 days later were 30 to 40 percent higher. For this reason, the authors suggest that the lesser amount in March than in January and February cannot be attributed chiefly to maturity.

PARTS OF HEAD

Contribution from the Cornell station. Workers here have analyzed different parts of the cabbage head to determine the distribution of ascorbic acid in various parts of it (34). The heads of cabbage analyzed had been stored for two weeks after harvesting in a cellar with uncontrolled temperature and then in a refrigerator held at 40° F. The parts of the head were not analyzed immediately after harvesting. The inner leaves were found to be richer in the vitamin than either the

middle or the outer leaves (table 4). However, the rib portion of the outer edible green leaves gave the highest value of any of the parts tested.

INDIVIDUAL HEADS

Contributions from Rhode Island, Tennessee, and Texas stations. At the Rhode Island station (25) 10 heads of Copenhagen Market were tested to see how much variation there was among individual heads of different sizes. A positive correlation of 0.66 was found between weight of head and the amount of ascorbic acid.

The Tennessee station (8) noted in regard to size of individual heads: "There seemed to be a marked tendency for the smaller heads to have a higher ascorbic acid content as observed in the raw sampling." The Texas station (32) found that the ascorbic acid content in 5 small heads (598 to 870 gm) analyzed separately, was approximately 25 percent higher than in 11 large heads (1045 to 2125 gm). These two reports are not in agreement with the Rhode Island findings on the relation of size of head to ascorbic acid value.

STORAGE

Contributions from Cornell, Illinois, Minnesota, Ohio, Tennessee stations and the Charleston Laboratory. Since it is a common practice to store heads of cabbage for lengths of time varying from a few hours to a few months, the effect on ascorbic acid of this practice has been studied at six stations. Minnesota (16, 19) workers determined for a few lots of cabbage the effect of a 24-27 hour storage period at 5° C. compared to 0-5 hours of storage. They concluded that storage of the

TABLE 4.—Distribution of ascorbic acid in different parts of the cabbage head as reported by Cornell Station* (fresh weight)

Parts of Head	Ascorbic Acid	
	Average†	Range
	Milligrams per 100 grams	
Inner leaves	53	49–57
Middle leaves	41	39–43
Outer green leaves	45	42–48
Outer green leaves, ribs removed	44	37–48
Outer green leaves, ribs only	56	55–57

*J. Am. Dietet. Assoc. 22:677-682

†Based on 3 samples of 2 heads each

heads of cabbage for 24 hours at 5° C. did not affect the ascorbic acid content. The figures obtained in that part of the study and those for a few other storage periods are given in table 5.

The Charleston Laboratory (22) determined the ascorbic acid content of three strains of cabbage stored at room and at refrigerator temperatures for 1- and 2-week periods. One strain, Volga-2, retained a greater percentage of this vitamin during storage than the other two strains (table 6). After 2 weeks storage in a refrigerator the average loss for all strains was 11.0 percent as compared to 11.4 percent for storage at room temperature for the same period. Losses due to storage were small compared to those due to cooking.

TABLE 5.—Influence of storage on ascorbic acid* content in raw cabbage as reported by Minnesota Station

Variety or strain	Year	Length of time of storage	Ascorbic acid content in milligrams per 100 grams		Reference number
			Fresh weight	Dry weight	
Danish Ballhead	1942	4 hrs	42.2	——	19
Danish Ballhead	1942	29 hrs	47.6	——	19
Marion Market	1942	30–36 hrs	41.2	——	19
Marion Market	1942	50–56 hrs	37.8	——	19
Marion Market	1942	26–30 hrs	38.6	——	19
Marion Market	1942	50–54 hrs	44.2	——	19
Marion Market	1943	0– 5 hrs	32.3	491	19
Marion Market	1943	24–27 hrs	28.5	445	19
Marion Market	1943	0– 4 hrs	40.6	625	19
Marion Market	1943	24–27 hrs	37.2	555	19
Marion Market	1943	0– 4 hrs	36.9	576	19
Marion Market	1943	24–27 hrs	44.2	597	19
Marion Market	1944	5 hrs	30.6	——	16
Marion Market	1944	24 hrs	38.0	——	16
Marion Market	1944	4 hrs	37.9	——	16
Marion Market	1944	24 hrs	39.1	——	16
Golden Acre	1944	2 hrs	30.3	——	16
Golden Acre	1944	24 hrs	30.9	——	16
Golden Acre	1944	1 hr	34.5	——	16
Golden Acre	1944	5 hrs	33.8	——	16

*Determined by Morell indophenol method with Bessey correction for turbidity.

Illinois and Ohio stations used longer storage periods. The heads of cabbage at the Illinois station (30) were placed in tightly covered 50-pound lard cans and stored at —0.5° and 4.0° C. Those at Ohio (14) were wrapped in paper and stored in bushel baskets in a cold storage room at 4° to 5° C. The effect of storage as studied at these two stations is shown in table 7. The data on the dry weight basis takes into account the changes in moisture that occurred during storage. In the Illinois study when the ascorbic acid content was calculated on the dry weight basis there was a retention of at least 94 percent after 2 months of storage. Samples of one variety of cabbage removed from cold storage after 2 months of storage and held in a household refrigerator for 4 and for 7 days retained an average of 97 percent of the original ascorbic acid in both cases. Similar samples held for 3 days at

TABLE 6.—Influence of storage on ascorbic acid* retention in raw cabbage as reported by Charleston Laboratory†

Variety or strain grown in 1943	Conditions of storage	Length of time of storage	Ascorbic acid retention	
			Mg/100 gm.	Percent
Roundhead No. 18	Unstored	———	45.6	———
Volga-2	Unstored	———	66.7	———
Charleston Wakefield	Unstored	———	62.1	———
Average for all strains	Unstored	———	58.1	———
Roundhead No. 18	Refrigerator	1 week	48.9	107.2
Volga-2	Refrigerator	1 week	61.5	92.2
Charleston Wakefield	Refrigerator	1 week	56.5	91.0
Average for all strains	Refrigerator	1 week	55.6	95.7
Roundhead No. 18	Refrigerator	2 weeks	43.0	94.3
Volga-2	Refrigerator	2 weeks	63.0	94.5
Charleston Wakefield	Refrigerator	2 weeks	49.2	79.2
Average for all strains	Refrigerator	2 weeks	51.7	89.0
Roundhead No. 18	Room temp.	1 week	42.0	92.1
Volga-2	Room temp.	1 week	64.5	96.7
Charleston Wakefield	Room temp.	1 week	53.8	86.6
Average for all strains	Room temp.	1 week	53.4	91.9
Roundhead No. 18	Room temp.	2 weeks	36.2	79.4
Volga-2	Room temp.	2 weeks	62.5	93.7
Charleston Wakefield	Room temp.	2 weeks	55.7	89.7
Average for all strains	Room temp.	2 weeks	51.5	88.6

*Determined by Bessey and King titration method.

†Proc. Am. Soc. Hort. Sci. 45:396-404.

TABLE 7.—Influence of storage on ascorbic acid in raw cabbage as reported by Illinois and Ohio Stations

Location	Year	Variety or strain	Conditions of storage	Storage time	Fresh Weight		Dry Weight		Reference number
					Ascorbic acid mean	Retention	Ascorbic acid mean	Retention	
				Months	Mg/gm	Percent	Mg/gm	Percent	
Illinois	1942	Racine Market	—0.5° to 4.0° C	1	.49 ± .02*	104	7.3 ± 0.2	114	30, 14
Illinois	1942	Racine Market	—0.5° to 4.0° C	2	.39 ± .02*	83	6.2 ± 0.3	97	30, 14
Illinois	1942	Racine Market	—0.5° to 4.0° C	3	.37 ± .01*	79	5.8 ± 0.2	91	30, 14
Illinois	1942	Resistant Detroit	—0.5° to 4.0° C	2	.42 ± .01*	88	6.3 ± 0.2	98	30, 14
Illinois	1942	Resistant Detroit	—0.5° to 4.0° C + 3 days room temp.	2.1	.39 ± .01*	81	5.5 ± 0.2	86	30, 14
Illinois	1942	Resistant Detroit	—0.5° to 4.0° C + 4 days refrig.	2.1	.47 ± .01*	98	6.2 ± 0.1	97	30, 14
Illinois	1942	Resistant Detroit	—0.5° to 4.0° C + 7 days refrig.	2.2	.45 ± 01*	92	6.2 ± 0.2	97	30, 14
Illinois	1942	Wisconsin Golden Acre	—0.5° to 4.0° C	1	38 ± .02*	90	5.6 ± 0.2	96	30, 14
Ohio	1943	Golden Acre	5° C	1	.56†	95	6.8	109	14, 20
Ohio	1943	Golden Acre	5° C	2	.48†	81	5 9	94	14, 20

*Determined by Bessey and King titration method.

†Determined by Morell indophenol method.

room temperature after 2 months in cold storage contained 86 percent of the original ascorbic acid. Storage of one variety for a third month in cold storage at the Illinois station resulted in a 91 percent retention of ascorbic acid. The extent of moisture changes occurring during storage are shown by data from the Ohio and Tennessee (8) stations. The freshly harvested cabbage used by the Ohio station contained 91.8 percent moisture and the samples tested at 1 and 2 months contained approximately 90.8 percent. The Tennessee station reported a variation in dry matter content of cabbage purchased on the open market of from 11.3 percent for "winter" cabbage to 7.3 percent for "spring" cabbage.

The workers at the Cornell station (34) stored freshly harvested cabbage of a Danish variety in a cellar with uncontrolled temperature for 2 weeks and then moved it to a refrigerator maintained at 40° F. This supply was used for different experiments from the latter part of November through February. The workers report that there was no appreciable change in the vitamin content during the storage period.

CUTTING BY DIFFERENT METHODS

Contribution from Cornell station. The changes in ascorbic acid in cabbage due to cutting were investigated by the Cornell station (34) in a study of institution food service. The cutting of the cabbage was done by four different methods: shredding on Hobart machine, chopping on a Buffalo chopper, chopping in wooden bowl, and shredding on a slaw cutter. The ascorbic acid loss during the cutting was found to range from 9 to 15 percent for the four methods (table 8). It was pointed out by the Cornell group that the trend shown by these figures is probably accurate, but that the figures are based on the assumption that cabbage retains 100 percent of its vitamin C when shredded by means of a sharp knife on a board during routine sampling of the vegetable. That the assumption was not strictly true was shown by supplementary analyses of cabbage not locally grown. Unshredded wedges added to the stabilizing acid in the mechanical blender showed about 15 percent more ascorbic acid than similar samples shredded before adding to the acid.

HOLDING OF RAW CUT CABBAGE

Contributions from Cornell, Illinois, Maine, Ohio, Texas, and Utah stations. From the standpoint of the homemaker or the institution food service director, it is of importance to know whether or not cabbage can be prepared ahead of cooking or serving time without considerable loss

TABLE 8.—Effect of cutting raw cabbage by four different methods as reported by Cornell Station*

Method of cutting	Ascorbic acid before cutting	Retention immediately after cutting†
	Mg/100 gm.	Percent
Shredded on machine‡	43	88 ± 1
Chopped on chopper§	42	91 ± 2
Chopped in wooden bowl	42	90 ± 2
Shredded on slaw cutter	44	85 ± 1

*J. Am. Dietet. Assoc. 22:677-682.
†Assuming 100 percent retention in cabbage chopped on a board with a sharp knife
‡Hobart machine used.
§Buffola chopper used.

of ascorbic acid. Ohio, Maine, Texas, Utah, and Illinois stations have studied this question from the standpoint of the homemaker. At the Ohio (14) and Illinois (30) stations raw cabbage was shredded with a sharp knife and portions of it allowed to stand under three different conditions: 1 hour in air; 1 hour in water; and 3 hours in water. A comparison of findings is shown in table 9. There was little loss of ascorbic acid under any of these conditions.

Workers at the Maine station (5) shredded cabbage with a sharp stainless steel knife, placed samples in glass bowls and covered the bowls with waxed paper. These samples were allowed to stand at room temperature for three different periods: 15 minutes, 1 hour, and 2 hours. Three varieties were tested under these conditions. The results show that there was no loss of ascorbic acid in any of the varieties even after holding for 2 hours.

The Utah station (33) made a study of the effect of holding on the reduced ascorbic acid in samples of shredded and chopped cabbage held at refrigerator temperature for 1½ hours and at room temperature for the same length of time. Tests were made at 30-minute intervals. One-half of a head was shredded on a hand kraut shredder and the other half was chopped for 15 seconds in a Hobart electric food chopper. The losses during shredding and chopping were 10.1 and 11.9 percent, respectively, which were greater than the additional losses incurred during subsequent holding. Determinations of the total and the dehydroascorbic acid were made by this same station on another group of samples held under similar conditions. The amount of dehydro-

TABLE 9.—Effect of holding on the ascorbic acid value of raw shredded cabbage

Location	Variety	Basis for figures	Freshly shredded	Ascorbic acid retention of shredded cabbage held at room temperature for:						Reference number
				15 min. air	30 min. air	1 hour air	1 hour water	2 hours air	3 hours water	
			Mg/100 gm.	Percent	Percent	Percent		Percent	Percent	
Illinois	Racine Market	4 lots	40 ± 1	———	———	97 ± 2	94 ± 1	———	96 ± 2	30
Ohio	Marion Market	20 heads in duplicate	58	———	———	103	86	———	86	14
Maine	Drumhead Savoy	2 tests	43.59	103.9	———	101.3	———	101 4	———	5
Maine	Mammoth Rock Red	2 tests	100.74	99.1	———	98.7	———	101.6	———	5
Maine	Wisconsin #8 Ballhead	2 tests	70.58	101.4	———	102.4	———	104.2	———	5
Cornell										
Shredded on machine*	Danish	5 replicates on 7 lb.	43	———	86 ± 1	———	———	85 ± 2	———	34
Chopped on chopper †	Danish	5 replicates on 7 lb.	42	———	88 ± 1	———	———	88 ± 0	———	34
Chopped in wooden bowl	Danish	5 replicates on 7 lb.	42	———	88 ± 2	———	———	87 ± 3	———	34
Shredded on slaw cutter	Danish	5 replicates on 7 lb	44	———	81 ± 2	———	———	84 ± 2	———	34
Utah										
Shredded on kraut shredder	Danish Ballhead	10 tests	50.4	———	87.1	88.9	———	93‡	———	33
Chopped in chopper	Danish Ballhead	10 tests	50.4	———	82.3	82.5	———	83.1‡	———	33

*Hobart machine used. †Buffalo chopper used. ‡1 ½ hours at room temperature.

ascorbic acid increased during chopping. The loss due to chopping was only 6 percent when calculated on the basis of total ascorbic acid. The losses due to holding of the cut cabbage were negligible.

Incidental to other experiments, the Texas station (32) allowed six samples of chopped cabbage on uncovered enamel plates to remain on a laboratory table for periods ranging from 1¾ to 5 hours. Differences between the fresh and corresponding held sample in every case were negligible and well within the limits of variation between fresh samples.

The Cornell group (34) studied the effect of holding cut cabbage as practiced in institution food service. The raw shredded cabbage was held in an 8-quart dishpan at room temperature (78° to 82° F.) for 30 minutes and 120 minutes. It is evident from the results as shown in table 9 that only small losses of ascorbic acid occurred on standing.

HOLDING OF CUT CABBAGE TO WHICH DRESSINGS HAVE BEEN ADDED

Contributions from Maine and Utah stations and Southern Cooperative group. In the study conducted at the Maine station (5) on the holding of raw cabbage, the pH in shredded cabbage served as a control for other samples which were tested for the effect of the additions of salad dressings. French dressing made with cider vinegar of 5 percent acidity was added to samples from each of the three varieties studied and a dressing containing evaporated milk and cider vinegar of 5 percent acidity was added to samples from one of the varieties. The plain shredded cabbage lost practically none of its ascorbic acid in 2 hours. Samples containing French dressing lost approximately 4.5 percent in 15 minutes, 7.2 percent in 1 hour, and 11.6 percent in 2 hours. The samples with the evaporated milk dressing lost none of their ascorbic acid in 2 hours. The report from this station states that this difference is probably due in part to the lower vinegar content of the evaporated milk dressing.

In another study from the Maine station (4) further investigation was made of factors that might affect the rates of loss during holding of cabbage salads. Kinds of vinegars, the titratable acidity of the vinegar (or acetic acid), materials of which the bowls containing the salad were made, and seasonings used in salad dressings were all studied. Salads containing French dressings made with cider and with tarragon vinegar of 5 percent acidity had all lost about 35 percent of their vitamin C at the end of 2 hours. When the acidity of the vinegar used in dressings

was varied the loss of vitamin C in salads held 2 hours at room temperature was proportional to the titratable acidity of the vinegar. The salads containing the 5 percent vinegar lost 34.3 percent, those with 3 percent lost 21.5 percent, and those with distilled water lost 0.8 percent. Salads containing plain 5 percent cider vinegar lost almost twice as much ascorbic acid as those containing French dressing made with the same kind of vinegar. The studies showed that the lower losses occurring in salads made with French dressing are due chiefly to the seasonings in the dressings rather than the oil. Metallic ions introduced from utensils may cause increased oxidation of ascorbic acid.

The Utah station (33) reported a retention of 72.2 percent of the ascorbic acid in salads made with salad dressing and held 1½ hours at room temperature as compared to 83.1 percent for those without dressing and held under the same conditions. The dressing was made of equal parts of cooked salad dressing and whipped cream.

The Southern Cooperative group (1) report a significant loss of ascorbic acid in coleslaw during serving. No details are reported concerning the method of preparation.

ASCORBIC ACID IN COOKED CABBAGE

COOKING IN DIFFERENT TYPES OF UTENSILS

Contributions from Cornell and Minnesota stations. The effect of cooking cabbage in various types of cooking utensils was investigated by the Minnesota station (16, 19) in the years 1942 to 1946 inclusive. Four types of cooking utensils were used in most of the experiments: open kettle, tightly closed kettle, pressure saucepan, and steamer. The percentages of ascorbic acid retained in the cooked vegetable and in the cooking water were reported. Of the five varieties studied, one of the varieties, Marion Market, was analyzed during each of the four years; another, Danish Ballhead, during three successive years; and the other three varieties, for one year each. As shown in table 10 considerable variation in results was obtained with each type of cooking utensil, but there was a trend toward a significantly greater conservation of ascorbic acid in the cooked cabbage when cooking was done in the tightly closed kettle, in the pressure saucepan, and in the steamer than when cooking was done in the open kettle. The mean retention of ascorbic acid for the open kettle method was 50 to 54 percent in 1942 for all varieties studied as compared to 30 to 37 percent in 1943, 1944, and 1945. In general the figures for the other three cooking methods in all years were considerably higher.

TABLE 10.—Effect of cooking cabbage in different types of utensils on ascorbic acid content as reported by Minnesota Station

Variety or strain	Year	Basis for figures	Raw fresh weight	Retention of ascorbic acid in the cooked cabbage						Ascorbic acid dissolved in cooking water						Reference number
				Open kettle	Loosely covered kettle	Tightly covered kettle		Pressure sauce pan	Steamer	Open kettle	Loosely covered kettle	Tightly covered kettle		Pressure sauce pan	Steamer	
						Minimum water	Slightly larger than minimum					Minimum water	Slightly larger than minimum			
			Mg/100 gm.			Percent						Percent				
Marion Market	1942	4 lots	40.4*	54	55	88	84	—†	76	42	34	1	3	4	2	19
	1943	7 lots	36.2*	34	—	—	73	63	63	49	—	—	3	4	3	19
	1944	4 lots	36.4*	31	—	—	76	75	71	46	—	—	2	3	2	16
	1945	4 lots	52.2*	34	—	—	61	70	68	51	—	—	9	10	8	16
Danish Ballhead	1942	1 lot	44.9*	50	76	86	71	84	76	43	32	5	10	6	2	19
	1943	4 lots	46.9*	30	—	—	44	44	50	48	—	—	3	4	3	19
	1944	4 lots	41 8*	34	—	—	50	57	60	46	—	—	6	8	2	16
Golden Acre	1944	4 lots	32.4*	33	—	—	74	74	72	37	—	—	1	2	0	16
Bugner	1945	4 lots	58.4*	34	—	—	58	72	62	50	—	—	4	7	4	16
Resistant Detroit	1945	4 lots	47.0*	37	—	—	63	71	69	47	—	--	9	12	9	16

*Calculated by the Ohio station from the author's data.
†Notation from original table "Average was not calculated because of the apparent gain in Lot 2."

Analyses were made of the cooking waters from the cabbage. In all except the open kettle method, there was only a small percentage of the vitamin which had dissolved into the water. With the open kettle method the solution into the cooking water varied from an average of 37 to an average of 51 percent. In both 1943 and 1944, Danish Ballhead and Marion Market varieties were cooked in the four types of cooking utensils. When Danish Ballhead variety was cooked in the tightly covered kettle, the pressure saucepan, and in the steamer the average retentions for the three types of utensils were 46 percent in 1943 and 55 percent in 1944 as compared to averages for Marion Market of 66 percent in 1943 and 74 percent in 1944. Varietal differences were not apparent when these two varieties were cooked by the open kettle method in each of the 2 years. Similar results were reported in later studies by the same group (17, 18).

On a quantity basis of preparation the Cornell station (34, 35) reported two studies on the conservation of ascorbic acid during the cooking of cabbage in three types of cooking equipment, i. e., the steamer, the steam-jacketed kettle, and the stock pot. In the first type of utensil the vegetable was cooked by steaming; and in the other two, by boiling. In one of the studies all three types of equipment were used in cooking 5-pound lots of cabbage; the steam-jacketed kettle and the stock pot were used in boiling 20-pound lots; and the steam-jacketed kettle was used in cooking 40-pound lots. In the other study, all three types of utensils were used in cooking 10-pound lots of cabbage and the steam-jacketed kettle was used in cooking 50-pound lots. A compilation of the results of the two studies is presented in table 11. Steamed cabbage retained a greater percentage of ascorbic acid than the boiled cabbage. Among the samples of boiled cabbage, those boiled in the steam-jacketed kettle retained somewhat larger amounts of ascorbic acid than those boiled in the stock pot. The cooking waters were analyzed from the 10-pound lots of cabbage cooked by boiling. Approximately one-third of the ascorbic acid was in the cooking water. In the steam-jacketed kettle and in the stock pot sufficient water had been used to immerse the vegetable.

VARIATION IN THE AMOUNT COOKED AT ONE TIME

Contribution from the Cornell station. In the two Cornell studies (34, 35) discussed in regard to the influence of kind of cooking utensils on vitamin retention, comparison may be made of the influence of the amount of cabbage cooked at one time. When 5- and 10-pound lots were steamed, the same percentages of ascorbic acid were retained. In

TABLE 11.—Effect of cooking different amounts of cabbage in different types of institutional utensils as reported by Cornell Station

Pounds of cabbage*	Percentage retention of ascorbic acid in cooked cabbage			Percentage retention of ascorbic acid dissolved in cooking water				Reference number
	Steamer	Steam-jacketed kettle	Stock pot on range	Steam-jacketed kettle		Stock pot on range		
	Average	Average	Average	Average	Range	Average	Range	
5	84	74	66	—	———	—	———	35
10	84 ± 1	57 ± 2	50 ± 2	34	32–38	41	36–47	34
20	———	71	52	—	———	—	———	35
40	———	58	———	—	———	—	———	35
50	———	53 ± 3	———	—	———	—	———	34

*The data on the 5, 20, and the 40 lb lots are comparable; the data on the 10 and 50 lb lots are comparable The cooking water was increased proportionately to the vegetable

the case of boiling in the steam-jacketed kettle and the stock pot, with the exceptions of the 10-pound lots, as the size of lot was increased the retention of ascorbic acid in the vegetable decreased. In steaming no water was added to either lot of cabbage. The cooking time for the stock pot was almost twice that for the steam-jacketed kettle. However, in both boiling methods the amount of water was increased proportionately with the weight of the cabbage.

VARIATION IN THE AMOUNT OF WATER USED

Contributions from Cornell, Illinois, Ohio, and Texas stations. The amount of water which gives best results when cooking cabbage has been a disputed question. From the standpoint of conservation of ascorbic acid in the cooked vegetable, results obtained at the four stations investigating this point favor the use of a small amount of water. At three stations, the cooking sample was a family size portion (4 servings)—400 gm of shredded cabbage at Ohio and Illinois, 300 gm chopped cabbage at Texas. At the Ohio station (14, 20, 21) the three variations in amount of water were, respectively, 400 ml, 800 ml, and 1600 ml designated in table 12 by the ratios of cabbage to water as 1-1, 1-2, and 1-4. At Illinois (30) the ratios were 2-1, 1-2, and 1-4, respectively, and at Texas (31) 3-1, 1-2, and 1-4.

The Cornell station (34, 35) reported a study made on 5-pound lots of cabbage boiled in a steam-jacketed kettle with 5 quarts and 20 quarts of water. The same group reported another study on 10-pound lots boiled in a stock pot on top of a range in 5 quarts and in 10 quarts of water.

The data from the four stations are brought together in table 12. With exception of one series of experiments at Cornell, slices boiled in stock pot, as proportion of cooking water increased, percentage retention of ascorbic acid in the drained cooked cabbage decreased. The proportion of ascorbic acid dissolved in the liquor increased as amount of cooking water increased, with one exception (Illinois, 1-4). The differences between retentions in the vegetable for ratios of 1-2 and 1-4 were greater in the Ohio and Illinois findings than in those of the Texas study. The differences between retentions with ratios of 1-1 and 1-2 in the two reports from Ohio were 18 and 14 percent; in Illinois, between 2-1 and 1-2, it was 18 percent; whereas, in the two reports from Texas the differences between 3-1 and 1-2 were 37 and 43 percent. About twice as much ascorbic acid was left in 300 gm of cabbage (Texas study) after cooking with 100 ml of water (little or none left) as when 600 ml and 1200 ml were used. Total retention, cabbage plus cooking water, was practically the same with the two larger volumes of water.

TABLE 12.—Ascorbic acid in cabbage as affected by variation in amount of water used for cooking

Location	Proportion of cabbage to water	Method of cooking	Ascorbic acid						Reference number
			Raw cabbage		Retained in cooked cabbage		Dissolved in cooking water (liquor)	Retained in cabbage and liquor	
			Fresh wt.	Dry wt.	Fresh wt.	Dry wt.			
			Mg/100 gm.		Percent		Percent	Percent	
Ohio	1 – 1	Boiled 10 min. in	45.0	659.0	73	72	water absorbed	73	14, 21
Ohio	1 – 2	uncovered pan	45.0	659.0	51	59	42	93	14, 21
Ohio	1 – 4	"	45.0	659.0	31	45	60	91	14, 21
Ohio	1 – 1	"	55.3	——	55	—	32	87	20
Ohio	1 – 2	"	55.3	——	41	—	50	91	20
Ohio	1 – 4	"	55.3	——	29	—	65	94	20
Illinois	2 – 1	Boiled 7 min. covered.	41.5	——	78 ± 2	—	12 ± 1	89	30
Illinois	1 – 2	¾" slices	41.5	——	60 ± 3	—	24 ± 2	84	30
Illinois	1 – 4	"	41.5	——	51 ± 1	—	20 ± 4	71	30
Cornell	10 lb. – 5 qt.	Slices boiled in stockpot	46	——	58 ± 2	—	30	88	34
Cornell	10 lb. – 10 qt.	on range	46	——	50 ± 2	—	41	91	34
Cornell	5 lb. – 5 qt.	5 gal. steam-jacketed	—	——	74	—	—	74	35
Cornell	10 lb. – 10 qt.	kettle 7 min.	45	——	57 ± 2	—	34	91	34
Cornell	5 lb. – 20 qt.	5 gal. steam-jacketed kettle	—	——	64	—	—	64	35
Texas	3 – 1	Covered shallow pan	42.9	——	75	—	water absorbed	75	31
Texas	1 – 2	Boiled in covered beaker	42.9	——	38	—	35	73	31
Texas	1 – 4	"	42.9	——	34	—	36	71	31
Texas	3 – 1	Covered shallow pan	41.4	——	84	—	water absorbed	84	31
Texas	1 – 2	Boiled in covered beaker	41.4	——	41	—	33	74	31
Texas	1 – 4	"	41.4	——	36	—	37	74	31

SIZE OF PIECES

Contributions from Cornell and Michigan stations. Comparisons were made in a study reported by the Cornell station (34) of the retention of vitamin C in steamed and in boiled cabbage cut in wedges, slices, and shreds. According to this study, steamed cabbage cut in wedges retained a greater percentage of vitamin C than that cut in shreds (table 13). Boiled cabbage cut in wedges gave a higher retention than that cut in the other two sizes of pieces.

According to a report from the Michigan station (11), cooking 2000-gm lots of cabbage in 5000 gm of boiling water for 15 minutes resulted in a 45 percent retention in vitamin C in the moist samples of 1-inch cabbage wedges as compared to 54 percent for 3-inch wedges.

LENGTH OF TIME OF COOKING

Contributions from Cornell, Illinois, Minnesota, Ohio, Texas stations and the Charleston Laboratory. To what extent the length of time of boiling affects the amount of ascorbic acid in cabbage has been studied at six locations—the Cornell, Texas, Minnesota, Illinois, and Ohio stations and the Charleston Laboratory (table 14). The Illinois and Ohio workers compared relatively brief cooking times and used family size portions of the vegetable. The Illinois station (30) found that cabbage cooked for 7, 15, and 25 minute boiling periods showed no significant differences in the amount of ascorbic acid in the cooked cabbage. Ohio (14) compared 10 and 15 minute intervals and likewise found that there was little difference in the percentage of ascorbic acid in the cooked cabbage.

Texas station (31) reported no significant difference in ascorbic acid content of cabbage cooked 36 minutes and that cooked 18 minutes.

Minnesota (17) continued cooking in the open kettle for as long as 50 minutes after the cabbage was tender and in the pressure saucepan for 5 minutes, and reported no significant additional loss due to overcooking.

At the Charleston Laboratory (22), the problem was approached from the standpoint of longer boiling times and smaller quantities of the vegetable cooked at one time. Fifty-gram samples were placed in 400-ml beakers in 50 ml of water and boiled for 30 and 120 minutes, respectively. For the longer cooking time additional portions of water were used. At the end of each cooking period water was added to bring the beaker and contents to the original weight. The contents of the beaker were added to the extractant and an analysis was made. Results were obtained for three varietal strains of cabbage and for samples both

TABLE 13.—Effect of size of pieces on the retention of ascorbic acid in cooked cabbage

Location	Method of		Proportion of cabbage to water	Cooking time	Ascorbic acid		
	cooking	cutting			Raw	Retention	
						Drained cabbage	Cooking water
				Min.	Mg/100 gm.	Percent	Percent
Cornell*	Steamer	Wedges	5 lb – 0	10	45 (35–55)	85 ± 4	———
Cornell		Slices	10 lb. – 0	9	45 (39–48)	84 ± 3	———
Cornell		Shreds	10 lb. – 0	4	43 (32–51)	72 ± 4	———
Cornell	Steam-jacketed kettle	Wedges	5 lb. – 32 qt.	7–8	46 (34–53)	74 ± 6	———
Cornell		Slices	10 lb. – 10 qt.	7	45 (42–50)	57 ± 2	34 (32–38)
Cornell		Shreds	10 lb. – 6 qt.	4	42 (36–45)	57 ± 4	30 (14–37)
Michigan†	Boiled uncovered	3″ Wedge	2000 to 5000 gm.	15	50.2 ± 6.63	54	———
		1″ Wedge	2000 to 5000 gm.	15	50.2 ± 6 63	45	———

*J. Am. Dietet. Assoc. 22:677-682.

†J. Am. Dietet. Assoc 23:120-124.

TABLE 14.—Effect of increasing the length of the boiling period on the ascorbic acid content of cabbage

Location	Variety	Length of boiling period	Ascorbic acid in raw cabbage	Ascorbic acid			Reference number
				Retained in cooked cabbage	Dissolved in cooking water	Destroyed	
		Min.	Mg/gm.	Percent	Percent	Percent	
Illinois	Wisconsin Golden Acre	7	0 41 ± 0 02	55 ± 2	23 ± 2	22 ± 3	30
		15	——	52 ± 1	32 ± 0	16 ± 1	30
		25	——	52 ± 2	28 ± 0	20 ± 2	30
			Mg/100 gm.				
Ohio	Copenhagen Market	10	56	54	34	12	14
		15	56	54	36	10	14
	All Seasons	10	51	51	35	12	14
	All Seasons	15	51	53	35	12	14
Charleston	Roundhead #18	30	45.6	50*	—	—	22
	Roundhead #18	120	45.6	10*	—	—	22
	Volga-2	30	66.7	43*	—	—	22
	Volga-2	120	66.7	18*	—	—	22
	Charleston Wakefield-1	30	62.1	50*	—	-	22
		120	62.1	22*	—	—	22
Cornell	Danish	7	——	74	—	—	35
	Danish	20	——	51	—	—	35
Texas	Charleston Wakefield	18	54 8*	23*	27*	50*	31
		36	54.8*	21*	25*	54*	31

*Calculated from original data.

unstored and stored for short periods at two different temperatures. The samples cooked 120 minutes showed considerably greater average loss of vitamin C than those cooked 30 minutes. All three strains of cabbage, whether stored or unstored, lost vitamin C at about the same rate during cooking.

Two cooking periods, 7 and 20 minutes, were used at the Cornell station (35) when 5-pound lots of cabbage were boiled in a steam-jacketed kettle. The shorter cooking time gave 74 percent retention of vitamin C as compared to 51 percent for the longer time.

DEGREE OF DONENESS

Contribution from Illinois station. Illinois workers (30) cooked 400-gm samples of cabbage to the same degree of doneness as judged subjectively. The lengths of cooking periods varied with the method used. The three procedures followed were: boiling in 800 ml of water for 7 minutes with a cover on the pan; boiling in the same quantity of water for 8.5 minutes without a cover; and boiling in twice the quantity of water for 5.5 minutes uncovered. The results of the study are presented in table 15. The first procedure resulted in a slightly higher percentage retention of ascorbic acid in the cooked cabbage than the other two procedures. There was practically no difference in the results obtained by the second and third procedures. The percentage of vitamin C in the cooking water was somewhat less and the percentage lost was somewhat more when the larger amount of water was used in boiling than when smaller amounts of water were used.

TABLE 15.—Effect of cooking cabbage to the same degree of doneness by different methods as reported by Illinois Station*

Proportion of cabbage to water	Time of cooking	Method of cooking	Ascorbic Acid		
			Retained in cooked cabbage	Dissolved in cooking water	Destroyed
	Min.		Percent	Percent	Percent
1–2	7 0	Covered	56 ± 2	20 ± 2	24 ± 3
1–2	8 5	Uncovered	50 ± 2	23 ± 2	26 ± 4
1–4	5 5	Uncovered	49 ± 1	14 ± 3	36 ± 2

*Food Research 9·164-173.

SEASONS

Contribution from Texas station. Cabbage from the spring planting that was cooked in different amounts of water and for different lengths of time by workers at the Texas station (31) showed an average total retention between 45 and 50 percent. Cabbage from the fall planting retained from 72 to 80 percent under similar treatments. The authors suggest that more tests need to be made to determine whether this seasonal difference is characteristic.

ADDITION OF SALT

Contribution from Cornell station. Cornell workers (34) cooked cabbage in a steam-jacketed kettle with and without salt. The addition of salt to the cooking water resulted in a 10 percent greater retention of vitamin C in the vegetable and 10 percent less solution in the cooking water than did the omission of salt in the water for cooking.

ADDITION OF FAT

Contributions from Michigan and the Southern Cooperative group. In a study by the Southern Cooperative group (1) it seemed that fat increased the "apparent loss" of ascorbic acid as calculated on a dry weight basis. No provision was made in the experiment to determine the fat increment in the cooked food, so its effect on the change during cooking could not be calculated. In a later study by Dodds and others (7) at one of the participating stations, this question was investigated further. Fat was added in the amounts of 0, 2, 4, and 6 percent of the weight of the raw cabbage. The retentions of ascorbic acid among these samples with these amounts of added fat were 78.2, 75.9, 78.0, and 77.2 percent, respectively. The differences among these values were not significant.

Michigan (11) reported that there seemed to be no evidence that fat had an effect on the retention of vitamin C in the cooked cabbage.

HOLDING OF COOKED CABBAGE

Contributions from Cornell, Illinois, Michigan, Ohio stations and the Southern Cooperative group. Investigators at Ohio, Illinois, Cornell, Michigan and the Southern Cooperative group reported on various phases of this problem of holding cooked cabbage. Table 16 gives the conditions and time of holding followed in the studies at the Ohio (14), Illinois (30), and Cornell (34) stations. When the cooked cabbage was held in the refrigerator from 24 to 72 hours and then

TABLE 16.—Effect of holding on the ascorbic acid content of cooked cabbage

Location	Ascorbic acid in raw cabbage	Cooked	Ascorbic acid retention				Reference number
			Cooked, held in refrigerator		Cooked, held in double boiler		
			24 hours and reheated	72 hours and reheated	1 hour	2 hours	
	Mg/100 gm.	Percent	Percent	Percent	Percent	Percent	
Illinois	40 ± 2	57 ± 2	29 ± 3	24 ± 4	———	———	30
Ohio	49	45	35	———	12	4	14
Cornell	44	59 ± 3	20 ± 4*	———	———	———	34
			16 ± 2†				

*Reheated in steamer.

†Reheated in steam-jacketed kettle in fresh water

reheated, the retention was from 24 to 35 percent of the value of the raw cabbage. When the cooked cabbage was held over hot water 1 and 2 hours, the retention decreased from 45 percent to 12 and 4 percent, respectively.

The study made at Cornell (34) on institution food service indicated that significant loss occurred in cooked cabbage during holding in a refrigerator for 24 hours. There was a further significant loss when this stored cabbage was reheated in a steam-jacketed kettle in fresh water but when it was reheated in a steamer the additional loss was not significant.

Michigan (11) reported on the effect of holding cooked cabbage on a steam table as used in institutions. The size of pieces, time of holding, and temperature of the steam table were factors considered. Three-inch wedges of cabbage retained a somewhat greater percentage of vitamin C than 1-inch wedges when the steam table was held at 90° C., but size of piece was not a factor when the temperature was 100° C. The losses during the first 30 minutes were less than 10 percent for all conditions studied. At the end of 60 minutes the losses had increased to approximately 27 percent in both the 3-inch and the 1-inch wedges held at 100° and to 12 percent in the 1-inch wedges held at 90° C. The loss was only 7.7 percent for the 3-inch wedges held at 90° C. for 60 minutes.

In a study made at the Cornell station (34) cooked cabbage was held warm for serving as follows: (a) on the steam counter over water just below boiling, (b) in the "Thermotainer" at approximately 83° C., and (c) in the warmer at approximately 83° C. Samples held warm in these three types of containers were tested for vitamin C at the 0-, 15-, 30-, and 120-minute intervals. Significant losses resulted from holding cabbage for 15 minutes or longer in the "Thermotainer" and in the warmer, and for 30 minutes or longer on the steam counter.

The Southern Cooperative group (1) reported information on the losses of ascorbic acid during three serving intervals from a steam counter. The average ascorbic acid value for 13 samples of fresh cabbage at the beginning of the serving period was 191.2 mg per 100 gm, dry basis, as compared to 170.8 mg at the end of a 15-minute period and 182.6 mg at the end of a 30-minute serving period. Statistical analyses indicated that the losses during the serving period were not significant.

COMBINATION OF FACTORS

Contributions from Tennessee station and the Southern Cooperative group. The Southern Cooperative group (1) made studies on the nutritive value of 14 commodities as served. Cabbage was among this

group. Analyses of 22 samples of cabbage gave a mean ascorbic acid content of 647.8 (S.D. 188.4) mg per 100 gm dry weight of cabbage prepared for cooking, and 178.4 mg for the mean value of cabbage as served. The mean apparent loss was calculated to be 72.5 (S.D. 4.7) percent. The authors have stated that the interference of fat from the cooked cabbage in making dry matter determinations may have been an error of such magnitude that the true loss may or may not be significant. The mean ascorbic acid value for the cooked cabbage on the wet basis was 22.4 (S.D. 7.3) mg per 100 gm.

Data were available on four samples for calculating the losses due to cooking and holding. Losses during preparation for cooking are not included. The cabbage was cooked, held for variable periods and then placed on a steam table and held for 30 minutes. The ascorbic acid value of the raw cabbage after preparation for cooking was 613.8 mg per 100 gm, dry basis; of the cooked cabbage, 504.8 mg; and of the cooked cabbage held for 30 minutes on the steam table, 250.6 mg.

The regression of loss on the original amount of vitamin C was computed for 13 commodities. For cabbage, the regression was 1.02 and the mean apparent loss was 72.5 percent. The errors in dry matter determinations may account for the regression being higher than the percentage loss. In general the ascorbic acid losses in leafy commodities approximated a constant percentage of the original amount. The loss due to cooking represented the principal vitamin C loss from the raw to the "as served" product.

Workers at the Tennessee station (6) studied the factors that interfere with the calculation of the retention of vitamin C in cabbage as served. The least change was noted in moisture and solubility loss in cabbage that was steamed and to which no seasonings had been added. The general conclusions reached were that the most uniform loss was that due to cooking; a change to the dehydro form occurred during cooking; and the ascorbic acid of cooked cabbage is dependent on final seasonings such as salt and fat and may not be correctly expressed as a percentage retention of the raw product on either the wet or dry basis.

THIAMINE IN RAW CABBAGE

The outstanding vitamin value of cabbage is due to its ascorbic acid content, and yet it is considered a fair to good source of thiamine. This may account to a certain extent for the fact that the number of studies made on the ascorbic acid content of cabbage is large as com-

pared to that made on the thiamine content. Charleston Laboratory and the Cornell station determined the thiamine values of cabbage in connection with the National Cooperative Project.

VARIETY

Contribution from the Charleston Laboratory. Variations were noted in the thiamine content of seven strains of cabbage tested at the Charleston Laboratory (22). The highest value was 83.4 mcg per 100 gm for an experimental strain designated as Charleston Wakefield-1; the lowest, 56.4 mcg for a commercial strain of Copenhagen Market, and the average, 70.0 mcg. Arranged in the order of decreasing amounts, the thiamine contents in mcg per 100 gm fresh weight of the different varieties were:

Charleston Wakefield-1	83.4
Volga-1	78.0
Marion Market	73.3
Charleston Wakefield	69.5
Round Head No. 18	65.7
Volga-2	63.7
Copenhagen Market	56.4
Average	70.0

SEASONS

Contribution from the Charleston Laboratory. Poole et al. (22) found that there was a significantly larger amount of thiamine in cabbage grown in the late spring and harvested in June than there was in the same strains grown in the late winter and harvested in February. The opposite was true for the vitamin C content. The averages of five strains were 68.6 and 57.3 mcg per 100 gm for the June and February harvest, respectively (table 17).

PARTS OF HEAD

Contribution from the Cornell station. Different parts of the cabbage head were analyzed for thiamine at the Cornell station (34) and found to vary as much as seven-fold. The inner leaves contained an average of 0.164 mg per 100 gm as compared to approximately 0.040 for the middle and the outer green leaves. The rib in the outer green leaves contained an average of 0.023 mg.

TABLE 17.—Influence of seasons on thiamine content* of raw cabbage as reported by Charleston Laboratory† (fresh weight)

Variety or strain	Thiamine		
	February	June	Seasonal differences
	Micrograms per 100 grams		
Copenhagen Market	51.2	56.2	5.2
Roundhead No 18	58.9	65.7	6.8
Marion Market	63 8	73.3	9.2‡
Volga-1	56.2	78.0	21.8§
Charleston Wakefield	56.6	69.5	12.9‡
Average	57.3	68.6	8.7‡

*Thiamine determined by modification of Conner and Straub method
†Reported in Proc. Am Soc Hort Sci 45 396-404
‡Significant at 5 percent level
§Significant at 1 percent level

HOLDING OF RAW CUT CABBAGE

Contribution from the Cornell station. Cabbage prepared in institution food service at Cornell University was cut by four different methods, i. e., (a) shredding on a Hobart machine; (b) chopping on a Buffalo chopper; (c) chopping in a wooden bowl; and (d) shredding on a slaw cutter. Based on the assumption that cabbage cut with a sharp knife on a board for sampling retained 100 percent of the vitamin, there was no loss due either to cutting by any of the four methods or to holding the cut cabbage at room temperature for 30 minutes and for 2 hours (34).

THIAMINE IN COOKED CABBAGE

COOKING IN DIFFERENT TYPES OF UTENSILS

Contribution from the Cornell station. The workers at the Cornell station (34) investigated several aspects of the problem of vitamin retention and losses during cooking. Cabbage was cooked by steaming and by boiling. That cooked by steaming retained a higher percentage of thiamine than that cooked by boiling in either a steam-jacketed kettle or in a stock pot on a range. The percentages of retention were 85, 63, and 50, respectively, in the cabbage cooked in these three ways. The amount that leached into the cooking water was 41 percent in the case of the cabbage boiled in the steam-jacketed kettle as compared to 47 percent in that boiled in the stock pot. There was practically no destruction of thiamine during the boiling of cabbage. A statistical

analysis of these data showed that steamed cabbage contained significantly more thiamine than boiled cabbage. Since the cooking water is often discarded and it is usually only the portion of the vitamin found in the cooked vegetable that is consumed, the method of cooking cabbage would seem to be important.

VARIATION IN THE AMOUNT COOKED AT ONE TIME

Contribution from the Cornell station. Increasing the quantity of cabbage boiled in one lot from 10 to 50 pounds with a proportional change in the amount of water, had little effect on thiamine. Sixty-one and 69 percent, respectively, were retained by the two procedures (34).

VARIATION IN THE AMOUNT OF WATER USED

Contribution from the Cornell station. In the Cornell study (34) the amount of water used for boiling was decreased from an amount sufficient to cover the sliced cabbage (10 quarts water to 10 pounds cabbage) to half that amount (5 quarts water to 10 pounds of the vegetable). With the larger proportion of water, the cooked vegetable had 50 percent of the original amount of thiamine, compared to 65 percent retention when less water was used. In both methods, the thiamine lost from the vegetable was present in the cooking water.

SIZE OF PIECES

Contribution from the Cornell station. A comparison of three methods of cutting the cabbage before steaming or boiling in the steam-jacketed kettle showed that cabbage cut in wedges retained more thiamine than that cut in either slices or shreds. Steamed wedges retained an average of 92 percent of the original thiamine; boiled wedges, 85 percent; steamed slices, 85 percent; boiled slices, 61 percent; steamed shreds, 77 percent; and boiled shreds, 64 percent (34).

ADDITION OF SALT

Contribution from the Cornell station. The Cornell station (34) prepared 10-pound lots of cabbage by boiling in the steam-jacketed kettle with and without salt in the cooking water. The thiamine retention in the cooked cabbage when salt was used was 55 percent compared to 59 percent when salt was omitted. The difference was estimated to be within experimental error. More thiamine was present in the cooking water from cabbage cooked with salt than in that from cabbage cooked without salt (47 and 34 percent, respectively).

HOLDING OF COOKED CABBAGE

Contribution from the Cornell station. The Cornell investigators (34) found no appreciable loss of thiamine due to holding drained, cooked cabbage by any of the three methods used to keep it hot for serving, i. e., on a steam counter; in a warmer; and in a heated insulated unit. For samples of cooked cabbage stored in the refrigerator for 24 hours and then reheated, the figures showed no definite trend. Fifty-nine percent of the thiamine in the raw cabbage was retained during cooking; 46 percent during refrigeration of the cooked cabbage for 24 hours; and 65 and 52 percent during reheating by steaming and boiling, respectively. The losses during storage and reheating were not significant.

RIBOFLAVIN IN RAW CABBAGE

Although cabbage is not outstanding as a source of riboflavin, according to tables of food composition it contains approximately 70 mcg per 100 gm, fresh basis. Studies on the riboflavin content of cabbage were made by six of the locations working on the National Cooperative Project.

VARIETY

Contributions from Cornell and Illinois stations, the Southern Cooperative group, and the Charleston Laboratory. The Charleston Laboratory (22) has reported data for the riboflavin content of seven varieties and strains of cabbage immediately after harvesting in June, 1943. Approximately 12 heads of each strain were composited for the samples taken. The values in mcg per 100 gm fresh weight, arranged in order from highest to lowest are:

Volga-2	44.0
Charleston Wakefield-1	33.7
Charleston Wakefield	29.5
Volga-1	28.2
Marion Market	21.1
Round Head No. 18	16.9
Copenhagen Market	16.9
Average	27.2

Resistant Detroit variety of cabbage, grown under known conditions, was tested for riboflavin content after approximately 2 months of storage by the workers at the Illinois station (29). They reported an average of 0.56 mcg per gm in the raw cabbage (equivalent to 56 mcg per 100 gm). Other samples, variety unknown, purchased on the market for comparison contained 0.52 mcg.

The cabbage used for the quantity food preparation studies at Cornell station (34) was described as being a "Danish variety containing a mixture of strains and breeding materials". The average of 80 samples tested was 0.045 ± .012 mg of riboflavin per 100 gm of raw cabbage (45 ± 12 mcg), with a range from 0.027 to 0.085 mg.

The Southern Cooperative group (15) reported a value of .073 mg per 100 gm of raw cabbage. No mention was made of variety or source.

SEASONS

Contribution from the Colorado station. The cabbage purchased on the market for use in the Army Student Training Program mess at Colorado State College (23) was analyzed for riboflavin content. The mean levels of samples tested during four periods at 30-day intervals in the fall, winter, and spring of 1943-44 were as follows: .058, .063, .076, and .070 mg per 100 gm of fresh cabbage. The differences among periods were significant on the dry basis. The general trend toward higher values in the later periods is in direct opposition to that for the vitamin C values.

PARTS OF HEAD

Contribution from the Cornell station. The Cornell group (34), in analyzing cabbage used in a quantity food study, found that the inner leaves contained .080 mg per 100 gm of fresh cabbage and was the part of the head richest in riboflavin. The outer green leaves, rib removed, contained .059 mg; the middle leaves and the rib of the outer green leaves, .051; and the outer green leaves, .048.

CUTTING BY DIFFERENT METHODS

Contribution from the Cornell station. Investigators at the Cornell station (34) found that cut cabbage contained approximately 100 percent of the original amount of riboflavin whether the cutting was done by shredding on the Hobart machine, chopping on a Buffalo chopper, chopping in a wooden bowl, or shredding on a slaw cutter.

HOLDING OF CUT CABBAGE

Contributions from Cornell and Illinois stations. In the study mentioned above (34) the cut cabbage was held at room temperature for 30 minutes and 120 minutes. The workers reached the conclusion that the differences in riboflavin content due to holding were small and thought to be within experimental error. Hence it was concluded that holding cut cabbage did not appreciably affect the riboflavin value.

Studies at the Illinois station (29) showed that there were no significant decreases in the amounts of riboflavin in cabbage that had been shredded and allowed to stand for 2 hours in air and for 1 and 3 hours in water.

HOLDING OF CUT CABBAGE TO WHICH DRESSINGS HAVE BEEN ADDED

Contribution from the Colorado station. Colorado station (23) reported a value of 0.178 mg per 100 gm (wet basis) for coleslaw as prepared and 0.286 for that held for 75 minutes, a significant gain during the 75-minute holding period. No explanation was given.

RIBOFLAVIN IN COOKED CABBAGE

COOKING IN DIFFERENT TYPES OF UTENSILS

Contribution from the Cornell station. In comparing the effect of cooking cabbage in three different types of large quantity cooking utensils, the Cornell workers (34) found 82 percent average retention of riboflavin in cabbage cooked in the steamer without added water; 70 percent in that cooked in the steam-jacketed kettle; and 59 percent in that cooked in the stock pot on the range. The cooking waters from cabbage boiled in the two latter types of utensils contained an average of 38 and 45 percent, respectively, of the riboflavin originally present in the uncooked vegetable.

VARIATION IN THE AMOUNT COOKED AT ONE TIME

Contribution from the Cornell station. The effect of the amount of cabbage boiled at one time in a steam-jacketed kettle on the retention of riboflavin was found to vary considerably (large standard errors) for different samples according to investigators at the Cornell station (34). The average retention of four repetitions for 10-pound lots of cabbage was 70 $\pm$ 9 percent. For the 50-pound lots boiled in a proportional amount of water and for the same length of time, there was an average of 84 $\pm$ 9 percent retention of the riboflavin in the drained vegetable. These differences were not statistically significant.

VARIATION IN THE AMOUNT OF WATER USED

Contributions from Cornell and Illinois stations. Cabbage of Resistant Detroit variety, stored for approximately 2 months, was cooked in family size portions by boiling in two different proportions of water by workers at the Illinois station (29). The boiling time in each case was 10 minutes, but the amount of water for 400 gm of sliced cabbage was 200 ml in one series and 800 in the other, with four replications in each series. Retention of 74 percent of the riboflavin in the cooked cabbage occurred with the smaller proportion of water compared to 50 percent retention when more water was used. The smaller

amount of cooking water contained 20 percent of the riboflavin and 44 percent leached into the larger quantity of water. The destruction was the same for the two quantities of water used.

The same trend in relation to solution of riboflavin into cooking water was found in institution practice by the Cornell investigators (34). The cabbage boiled in a stock pot on the range in enough water to cover the vegetable (10 quarts for 10 pounds of cabbage) retained an average of 59 percent of the riboflavin in the drained cabbage, whereas 79 percent was retained by cabbage cooked in half as much water. The larger quantity of cooking water contained an average of 45 percent of the original riboflavin compared to 41 percent for the smaller amount of water. There was no apparent destruction of riboflavin during cooking.

SIZE OF PIECES

Contribution from the Cornell station. Three variations in size of pieces were used in the Cornell study (34) when cooking cabbage in an institution type steamer and in a steam-jacketed kettle. For both the steamed and the boiled cabbage, the highest retention of riboflavin was found in the pieces cut as wedges, 104 percent and 90 percent, respectively. Slices gave 82 percent retention when steamed and 72 percent when boiled. Shreds averaged 91 percent retention when steamed and 66 percent when boiled. Thus the method of cooking as well as the size of pieces were factors influencing the conservation of the vitamin. The cooking waters from the boiled slices and the boiled shreds were analyzed. An average of 38 percent of original riboflavin was found in the cooking water for each.

LENGTH OF TIME OF COOKING

Contribution from the Illinois station. In the study of stored Resistant Detroit cabbage, the Illinois station (29) compared the effect on riboflavin of 10 and 20 minute boiling periods. Family size portions of cabbage, 400 gm lots, were boiled in twice their weights of salted water. The average of four repetitions of each cooking period showed 50 percent retention of riboflavin in the cabbage cooked the shorter time and 47 percent in that cooked for the longer boiling time. The cooking water of the cabbage cooked 10 minutes contained 44 percent of the original riboflavin as compared to 49 percent in the water of that cooked 20 minutes.

ADDITION OF SALT

Contribution from the Cornell station. According to the results obtained in two replications at the Cornell station (34), the addition of salt to the water for boiling did not appreciably affect the percentage of

riboflavin retained in the cooked cabbage. These investigators boiled 10-pound lots of cabbage in 10 quarts of water in a steam-jacketed kettle with no salt and with 200 gm of salt. The drained cooked cabbage boiled in unsalted water retained 77 ± 2 percent of the riboflavin as compared to 78 ± 2 percent for that boiled in the salted water.

HOLDING OF COOKED CABBAGE

Contributions from Colorado, Cornell, and Illinois stations and the Southern Cooperative group. The Illinois station (29) workers boiled 400 gm of cabbage in 800 ml salted water for 10 minutes and tested samples for riboflavin. The cooked cabbage was allowed to stand at room temperature for 1 hour, refrigerated for 48 hours and then tested for riboflavin. The cooked refrigerated samples were reheated by boiling in 100 ml water for 2 minutes. The treatments were replicated five times. The average retention in the cooked cabbage was 51 percent; in the refrigerated samples, 47 percent; and in the reheated sample, 42 percent. The cooking water from the freshly boiled cabbage contained 46 percent of the original amount of riboflavin and the water from the reheated sample contained 9 percent. The data indicated that riboflavin was leached into the water but was not destroyed during cooking and reheating.

In a study made at the Cornell station (34) it was shown that the loss of riboflavin due to holding in a refrigerator and subsequent reheating of institution lots of cabbage was not significant. In another phase of this study at the Cornell station, freshly cooked cabbage was held warm for serving for as long as 2 hours without significant losses in riboflavin.

The Colorado station (23) reported the riboflavin content of cabbage as received and prepared was 0.066 mg per 100 gm; as cooked, 0.062 mg; and after holding on the steam table for 75 minutes, 0.094 mg. This represents a significant gain during holding. No explanation was given for this apparent gain.

The Southern Cooperative group (15) reported a 3 percent loss due to cooking and holding for 30 minutes after cooking. There was no loss due to holding for serving over a 1-hour period.

OTHER VITAMINS IN RAW AND COOKED CABBAGE

Contributions from Colorado and Rhode Island stations and the Southern Cooperative group. A very limited amount of data was presented on the carotene, pantothenic acid, and nicotinic acid content of cabbage. The Southern Cooperative group and the Rhode Island

station reported on the carotene content. According to the reports from these stations the amount of carotene in cabbage is very small. Slight differences among varieties or between fresh and cooked samples may be unimportant although they represent comparatively large percentage differences. The Rhode Island station (25, 26) reported on several different varieties of cabbage which were tested at intervals during two different seasons. In all cases the carotene content was relatively small and differences were not important. The Savoy variety was a somewhat better source of carotene than some of the more common varieties. The Southern Cooperative group (1) reported a value of 0.33 mg per 100 gm of cabbage prepared for cooking and 0.18 mg in the cooked cabbage. That lost from the cooked vegetable was found in the cooking water.

The pantothenic acid content of fresh cabbage was reported by the Colorado station (23). According to this report fresh cabbage contained 1.09 mg per 100 gm and the loss during holding of the cooked product on the steam table for 75 minutes was significant. Freshly prepared coleslaw contained 0.883 mg as compared to 0.571 mg for that held 75 minutes, a significant loss due to holding.

The niacin content of fresh cabbage was reported by the Colorado station (23). According to their findings fresh cabbage contained 0.555 mg per 100 gm, and coleslaw, 0.455 mg. The losses during the cooking of cabbage and during the holding of cooked cabbage and of slaw were not significant when tested on the wet basis. The coleslaw, but not the cooked cabbage, showed a significant loss during holding when calculations were made on dry basis.

PALATABILITY

Contributions from Cornell, Michigan, Minnesota, and Texas stations. The Cornell station (34) reported that both steamed and boiled cabbage were considered acceptable products, although that boiled in the steam-jacketed kettle or in a stock pot on the range was considered more palatable than the steamed cabbage. Boiling in steam-jacketed kettle gave the most acceptable product.

Michigan (11) reported a study in which the cooked cabbage was scored for palatability on the basis of a value of five for a highly desirable product. When cabbage was cut in different size pieces, cooked, and then scored, there seemed to be no relation between size of piece and palatability score. However, the palatability of cabbage held on the steam table was affected by the length of time the vegetable was held and by the temperature of the steam table. That held for 60 minutes

was definitely less palatable than that held for only 30 minutes. Cabbage held 15 minutes scored only slightly higher than that held for 30 minutes. The score for samples held at 90° C. was somewhat higher than that of the samples held at 100° C.

Minnesota (19) workers studied the acceptability of cabbage cooked in different types of utensils from the standpoints of flavor, odor, and color. In one study this group observed that cabbage cooked in the open kettle more nearly resembled raw cabbage in flavor and color than did the cabbage cooked in the steamer and in the tightly covered kettle. When cooked by the latter two methods the color was described as grayish-white and yellow-green and the odor was said to be strong. Cabbage cooked in the pressure saucepan for 3 minutes or less resembled the boiled product in color and odor; but if the cooking time was increased beyond the 3-minute period, the cabbage resembled that cooked in the steamer and tightly covered kettle. In a later study the Minnesota workers (16) used the Nickerson system of color notation for comparing hue, brilliance, and intensity of the cabbage samples. Samples of three varieties (Marion Market, Golden Acre, and Danish Ballhead) cooked in the open kettle were as green or greener than the hue of the original raw vegetable. Those cooked in the steamer and in tightly closed kettle lost their greenness and were yellow in hue. When cooking was done in the pressure saucepan, two of the varieties (Marion Market and Golden Acre) retained some of their green color but the third variety (Danish Ballhead) lost the green color and retained only the yellow hue. The method of cooking had no consistent effect on brilliance. The intensity of the samples cooked in the open kettle compared favorably with the intensity of the raw cabbage. Considerable decrease in intensity was noted in the samples cooked by the other methods.

The Texas station (31) made observations concerning the palatability of boiled and panned cabbage. The boiled cabbage was brighter in color and milder in flavor than the panned. That cooked twice the time necessary for the "just done" stage was very soft in texture. Cabbage boiled in one-third enough water to cover cooked unevenly and was unacceptable.

ASCORBIC ACID IN DEHYDRATED CABBAGE

DEHYDRATION

Contributions from Oregon and Texas stations and Charleston Laboratory. In a study made at the Charleston Laboratory (22) seven varieties of cabbage were steam blanched for 4 minutes and dehydrated

for 8 hours. The average loss of ascorbic acid due to dehydration for all strains was 84.2 percent. There was a varietal difference in retention of vitamin C during dehydration. The Volga-2 and Charleston Wakefield-1 breeding lines lost less vitamin C during dehydration than the commercial varieties, Copenhagen Market, Round Head No. 18, Marion Market, and Charleston Wakefield. The additional loss during the 3 months' storage period was not significant.

In a study made at the Texas station (24) the effect of certain storage factors on the vitamin C content and eating qualities were noted. Dehydrated cabbage was packed in tightly wrapped cartons with parchment inner liner, in tin cans, and in glass jars. Half of the jars and cans were vacuum-sealed under CO_2. Samples in all types of containers were held at room temperature and at refrigerator temperature (45° F.). A few jars were stored so as to be in direct sunlight about 2 hours on sunny days and the remainder in the dark. Samples were cooked and judged for eating qualities a few days after dehydration and after storage for 6 months. Cabbage stored in cartons at room temperature were inedible. Refrigeration protected the vitamin C content and palatability of cabbage in cartons. Samples in air-tight containers retained their vitamin C better at refrigerator temperature than at room temperature and those packed in CO_2 and stored at room temperature retained more vitamin C than those packed in air and held at room temperature. Storage in the dark conserved more vitamin C than storage in a strong light.

At the Oregon station (10) four varieties of cabbage were dehydrated. Three methods of pretreatment were applied to each variety: steam blanching for 5 minutes; sulfur treatment for 30 minutes; and sulfur dip for 1 minute. The losses in reduced ascorbic acid due to the combined effects of preparation for dehydration and dehydration itself ranged from 25 to 50 percent. The method of pretreatment and variety seemed to make relatively little difference. Samples of the dehydrated cabbage receiving these pretreatments were stored and samples tested at 3-month intervals during the 9 months following dehydration. Steam blanched samples were held as long as 12 months. There was a gradual loss of ascorbic acid in all samples during storage.

COOKING

Contribution from Oregon station. The Oregon station (10) reported that samples held 6 months were cooked and all the ascorbic acid in the uncooked sample at that time could be accounted for in the cooked product and the cooking water.

THIAMINE IN DEHYDRATED CABBAGE

DEHYDRATION

Contributions from the Oregon station and the Charleston Laboratory. The Charleston Laboratory (22) reported an average loss of 29.9 percent of the thiamine during dehydration. The concentrations of thiamine present in the vegetable before and immediately after dehydration are shown in table 18.

Oregon (10) reported a complete loss of thiamine following sulfur treatment and steam blanching. These workers noted that the results of the first treatment were to be expected and the loss during the steam treatment may have been caused by sulfur fumes from the samples that had been sulfured and were dehydrated in the same drier cabinet at the same time.

STORAGE

Contribution from the Charleston Laboratory. Samples of dehydrated cabbage were stored at room temperature in sealed glass jars for a period of 3 months. The average loss of thiamine attributable to storage was 8.2 percent, bringing the total loss due to dehydration and storage to 38.1 percent according to the workers at Charleston Laboratory (22).

RIBOFLAVIN IN DEHYDRATED CABBAGE

DEHYDRATION

Contributions from Oregon and Texas stations and the Charleston Laboratory. Texas (27) reported a mean value of 0.46 mg per 100 gm for 19 samples of dehydrated cabbage, with a range from 0.31 to 0.74 mg.

TABLE 18.—Effect of dehydration on the thiamine content of raw cabbage in seven varieties as reported by Charleston Laboratory* (fresh weight)

Treatment	Thiamine						
	Copenhagen Market	Roundhead No. 18	Marion Market	Volga-1	Charleston Wakefield	Charleston Wakefield I	Volga-2
	Micrograms per 100 grams						
Fresh	56.4	65.7	73.3	78.0	69.5	83.4	63.7
Dehydrated	39 9	45.0	55.6	55.1	52.5	51.4	44.9

*Proc Am. Soc. Hort. Sci. 45:396-404.

The Charleston Laboratory (22) reported an average value of 39 mcg per 100 gm for seven cabbage strains. This was an increase of 43.4 percent over the value for the fresh cabbage. No explanation was offered for this apparent increase. The method of pretreatment was not noted.

The Oregon station (10) reported on the riboflavin content of dehydrated cabbage. Samples of four varieties were subjected to three pretreatments, i. e., steam blanching for 5 minutes; sulfur for 30 minutes; and sulfur dioxide dip for 1 minute. The latter treatment caused a somewhat greater loss in riboflavin content than did either of the other two.

VARIETY

Contributions from the Oregon station and the Charleston Laboratory. The riboflavin content of dehydrated cabbage seems to be dependent upon the initial value of the raw cabbage and the treatment to which it is subjected during dehydration. Among the varieties tested at the Oregon station (10), Stone and Danish Ball retained larger percentages of the original amount regardless of treatments than did the Round Red Dutch and Savoy varieties.

Among the seven strains dehydrated at the Charleston Laboratory (22), only one strain lost riboflavin during dehydration and that loss was very small (0.3 mcg per 100 gm of fresh weight). No explanation was given for the apparent gain in the other six strains.

STORAGE

Contributions from the Oregon station and the Charleston Laboratory. Gradual losses occurred in storage over a 12-month period according to the report of the Oregon station (10). The opposite, an increase during storage for 3 months was reported by the Charleston Laboratory (22).

COOKING

Contribution from the Oregon station. Dehydrated cabbage, stored for 6 months and then cooked, contained very little riboflavin. A very small percentage was found in the cooking water (10).

OTHER VITAMINS IN DEHYDRATED CABBAGE

The Texas station (27) reported that dehydrated cabbage contained from 1.40 to 3.50 mg of pantothenic acid per 100 gm with an average of 2.00 mg and the average niacin content was 2.95 mg with a range of 1.90 to 4.20 mg.

SAUERKRAUT

Contribution from Minnesota station. Minnesota workers, Donelson and Sellers (9), reported on the ascorbic acid content of sauerkraut. Twelve samples of the raw and 10 brands of canned kraut were tested. The solids and juices were tested separately.

Raw kraut, both solids and juice, contained more ascorbic acid than the canned. The raw solids contained 21.9 and the juice, 23.6 mg per 100 gm as compared to 17.0 and 19.1 mg for the solids and juice, respectively, from the canned kraut.

The difference between the values for raw and canned was not significant. The juice contained significantly more ascorbic acid than the solids in both the raw and canned samples.

CALCIUM IN RAW AND COOKED CABBAGE

Contribution from Purdue University station. This one station (3) reported a study undertaken as a part of this cooperative project that dealt with calcium content of cabbage whereas all other studies had dealt with the vitamin content. Three varieties of cabbage were cooked in (a) tap water with 92 mg of calcium per liter; (b) softened water with 26 mg per liter; and (c) distilled water. The calcium content of the raw cabbage varied from 35.7 to 42.7 mg per 100 gm for the three varieties. Cabbage wedges, cooked for 10 minutes, in softened and in distilled water lost a significant amount of calcium but in tap water there was both a loss in one instance and gains in two instances among the three varieties but the differences were not significant. In the latter case according to the authors the loss from the vegetable may be offset by the absorption from the water.

SUMMARY OF FINDINGS

Ascorbic acid content varied widely among approximately 35 varieties and strains of cabbage tested by 11 stations. The values ranged from 32.40 to 100.74 mg per 100 gm fresh weight. Red cabbage contained larger amounts than the green varieties. Findings by different stations were not in agreement on seasonal variation. The ascorbic acid content varied for the same variety planted in the same season of successive years.

There seemed to be little evidence of a relation of maturity to ascorbic acid value.

Reports were not in agreement on the relation of size of head to amount of ascorbic acid.

Cabbage retained a relatively high percentage of its ascorbic acid value when stored either at room or refrigerator temperatures for as long as 2 to 3 days or in commercial storage or its equivalent for periods of 3 months. There was some loss of moisture during storage which must be taken into account in evaluating changes in ascorbic acid content.

Holding of raw cut cabbage for periods as long as 5 hours resulted in very little loss of ascorbic acid. The loss due to cutting (shredding and/or chopping) was greater than that due to holding. Addition of dressings to cut cabbage and subsequent holding resulted in a loss of ascorbic acid which was proportional to the titratable acidity of the vinegar.

Steamed cabbage contained proportionally more ascorbic acid than boiled cabbage. The percentage of ascorbic acid retained in drained boiled cabbage was inversely related to the amount of water used in boiling. The ascorbic acid found in the boiled cabbage plus that in the cooking water accounted for almost all of that found in the uncooked cabbage.

The larger the size of pieces of cabbage and the smaller amounts cooked at one time, in general, the greater was the retention of ascorbic acid.

The loss of ascorbic acid due to length of cooking time did not vary significantly provided the total time was comparatively short, such as 10 to 35 minutes. However, when the time was increased to 2 hours there was greater destruction due to the longer cooking periods.

Cooked cabbage lost a large percentage of its vitamin C content when held on a steam table or held in a refrigerator and reheated for serving.

Thiamine content varied with variety from 83.4 mcg per 100 gm to 56.4 mcg. Season and part of head were also factors in variability. Cabbage harvested in June contained more thiamine than that in February and inner leaves were richer in this vitamin than any other part of the head. Cutting and holding of raw cabbage and storage and reheating of cooked cabbage had no effect on thiamine content.

In general, the trend toward loss of thiamine due to the method of cooking, the amount cooked at one time, amount of water used, and size of pieces was similar to that for ascorbic acid.

Information reported on the riboflavin content of cabbage was limited. Variation due to variety ranged from 17 mcg per 100 gm to 85 mcg. There were indications of variation due to season and parts of head.

Riboflavin content was not affected by cutting and holding of raw cabbage.

Method of cooking, amount cooked at one time, amount of water used, length of time of boiling, holding, and addition of salt had little effect on the riboflavin content.

Wedges that were steamed retained a greater percentage of riboflavin than slices and shreds whether cooked in an institution type steamer or in a steam-jacketed kettle.

Palatability was affected adversely by holding cooked cabbage for periods longer than 30 minutes and at temperatures higher than 90° C. Steamed cabbage was judged less palatable than boiled. The green color was lost when cabbage was cooked in the steamer, in the tightly closed kettle, and in the pressure saucepan for longer than 3 minutes.

Dehydrated cabbage and sauerkraut contained less than one-half as much ascorbic acid as raw cabbage.

Large percentages of the vitamins other than ascorbic acid were destroyed by dehydration, storage, and cooking.

There was a significant loss of calcium in fresh cabbage cooked in softened and distilled water; the loss in tap water was not significant.

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PART II. REVIEW OF LITERATURE ON CABBAGE

By MARY ELOISE GREEN

INTRODUCTION

The experimental work done on cabbage under the National Cooperative Project on Conservation of the Nutritive Value of Foods has been presented in Part I of this bulletin. An objective outlined as part of the Project was to bring together the research findings in the literature pertaining to various commodities. Part II has been prepared to meet the objective for one vegetable, namely, cabbage.

The reports on cabbage reviewed here are those found in periodicals written in English and which appeared within the period of 1935 to mid-1952. The number of studies published prior to that time was small and the methods of analysis, particularly for vitamins, were not well established. This review is limited to the findings for vitamin values and for palatability of fresh cabbage. Lists of references pertaining to research on dehydrated cabbage and on sauerkraut are presented in the Appendix. Attention should be directed to Part I for the data on cabbage collected under the National Cooperative Project, since no further reference is made to the findings in this review although a number of the reports are found in journals, as indicated in Part I.

The major portion of the research reported in the literature and reviewed here was directed toward a study of the ascorbic acid values of cabbage as affected by various factors in growth, handling, and preparation for serving at the table. Small portions of the data were related to other vitamins and to palatability. The objectives set up by the workers were diverse in nature and many variations in procedure were followed. The findings are herewith assembled under selected headings and a few generalizations that seemed apparent from the data have been made.

ASCORBIC ACID IN RAW CABBAGE

The reports in the literature indicate that cabbage varies widely in ascorbic acid content. Variety, season, maturity, parts of the head, size of head, storage, and preparation for serving are factors that contribute to these variations. A few studies are cited in which the ascorbic acid content of raw cabbage was reported but there was insufficient information to identify the sample with specific factors.

Munsell et al. (63, 64, 65, 66, 67, 68) investigated the composition of a large number of food plants of Central America. Their findings for the total ascorbic acid content[1] of samples of cabbage collected in the field or purchased in the market in various locations within the countries were as follows in milligrams per 100 grams: (a) Honduras, 54.5, 53.0, and 41.3; (b) Guatemala, 65.6, 32.4, 39.4, and for purple cabbage, 69.5; (c) El Salvador, 39.2 and 51.7; (d) Nicaragua, 28.2; (e) Costa Rica, 38.1, 42.4, and for purple cabbage, 95.8; (f) Guatemala, for purple cabbage, 38.3. The ascorbic acid content of cabbage grown in Mexico was reported by Cravioto B. et al. (21) as 20.4 milligrams. Cabbage grown in Florida had an average of 54 milligrams of ascorbic acid, according to French and Abbott (30). The raw green cabbage used by Hewston et al. (36) in experiments on the effects of home cooking procedures was considerably higher in vitamin C content (708.6 and 795.5 milligrams, dry weight, respectively, for two lots of green cabbage) than for the white cabbage (470.1 milligrams). Clayton and Borden (18) compared the availability of the vitamin C in raw cabbage (and home canned tomato juice) with that in ascorbic acid tablets for four young healthy subjects. The cabbage was obtained in early spring from commercial cold storage and different heads varied in vitamin C content from 23.11 to 55.83 milligrams per 100 grams when tested after 1 to 8 days of storage in a household refrigerator. The authors concluded (p. 360), "the vitamin C of both raw cabbage and tomato juice was utilized as well as, or possibly better than, that in the tablets."

VARIETY

A large number of varieties and strains of cabbage have been developed and the ascorbic acid concentration of many samples of different cabbages has been determined. The range of average values noted in the literature was from 7 to approximately 181 milligrams of ascorbic acid. Burrell et al. (12) tested 30 varieties and strains and found values ranging from 0.480 to 1.809 milligrams per gram with an average of 1.002 milligrams. The average for the ten highest in ascorbic acid was 1.529 milligrams and for the ten lowest 0.592 milligram. The average values reported by Poole et al. (80) for 25 breeding lines in two seasons varied from 0.31 milligram per gram to 0.73 milligram. Gould et al. (32) investigated six varieties, three of which were termed summer types and contained 0.55 to 0.56 milligram per gram as compared to 0.26 to 0.30 milligram for three varieties designated as autumn types.

[1]Vitamin values in this review are expressed as the weight per 100 grams of cabbage, moist basis, unless otherwise indicated.

Murphy (69) studied varietal differences in the vitamin C content of cabbage grown at one location in Maine in 1939 and reported the highest average value was 0.48 milligram per gram for three Ballhead varieties. Average values within the range of 0.36 to 0.46 milligram per gram were obtained for other varieties tested. Janes (40) found no marked difference in ascorbic acid potency among several varieties of cabbage harvested at four locations in Florida in 1945-46 (range for all varieties, 43 to 61 milligrams).

The average ascorbic acid content of 14 varieties of cabbage used in dehydration studies in England by Allen et al. (1) was 66 milligrams (range, 29 to 108 milligrams). Pyke (83) studied 23 varieties grown in England and found values ranging from 7 to 94 milligrams. Ten varieties of cabbage grown in two locations in England, according to Lampitt et al. (52), varied from a mean of 0.57 milligram per gram for Primo and Pride of the Market to 1.24 for Early Offenham. In a later study Lampitt et al. (54) compared three English varieties with five South African varieties of cabbage grown in one location in England in the summer of 1948. The data indicated that English varieties were richer in ascorbic acid than the South African varieties. Dehydroascorbic acid was relatively high in six of the eight varieties tested. Seeds from the same source as those planted in England were also planted in two locations of South Africa in 1948. Although the number of plants from South Africa was small compared to the number from England, the indication was that location had little or no influence on vitamin C concentration for the varieties tested.

Hallsworth and Lewis (33) compared the ascorbic acid content of three varieties of cabbage grown under similar conditions in New South Wales. Succession variety contained an average of 55.36 milligrams; Copenhagen Market, 53.07; and Early Jersey Wakefield, 51.04. The varietal differences were found to be significant even after the effects of the head weight and solar radiation were removed.

Ten varieties of Canadian-grown cabbage produced in experimental plots in 1943 were found by Branion et al. (10) to contain an average of 70.3 milligrams of ascorbic acid. The Red Rock variety, with an average of 111.1 milligrams, was markedly higher in ascorbic acid than any other variety in the series. The lowest was Golden Acre with an average of 57.1 milligrams. The experiment was repeated in 1944 for eight of the ten varieties and two other varieties not previously included were added. Red Rock again had the highest amount, 118.8 milligrams, and Copenhagen Market was the lowest with 43.6 milligrams. The average for all the varieties grown that year was 60.3

milligrams and seven of the eight varieties for which data were available both years had a smaller concentration of ascorbic acid in 1944 than in 1943.

Smith and Walker (92) found significant differences among varieties which occurred independently of environmental fluctuations. Varieties were grouped according to time of maturity and shape of head. Among the early maturing varieties, the pointed head types were higher in ascorbic acid in general than those of the round headed type. Midseason flat and some late maturing flat varieties were lowest in ascorbic acid among the 23 varieties tested. The same workers reported on the significance of heredity as a factor in ascorbic acid content. Two lines were developed from a single plant and inbred for seven generations. The vitamin contents of these two lines were 47.5 and 52.4 milligrams. A third line developed from a second plant was inbred for five generations and produced cabbage containing 82.9 milligrams. The indications were that an inherent high level of ascorbic acid content can be developed through selection.

Walker and Foster (100) studied twenty-three F_1 progenies from crosses between an inbred line of cabbage high in ascorbic acid, 86.7 milligrams, with varieties much lower in the vitamin, 52.8 milligrams, but which were yellows-resistant. The mean ascorbic acid content of the F_1 generation was 66.9 milligrams, a value which was near both the arithmetic and geometric mean of the parents. These workers extended the study to eight F_2 progenies and concluded that ascorbic acid values of standard yellows-resistant varieties can be improved. Barr and Newcomer (4) found consistently higher values for tetraploid than for the diploid cabbage grown in two different years (1941 and 1942).

SEASONS

With but few exceptions, season has been found to affect the ascorbic acid content of cabbage. In general, the varieties harvested in spring and early summer contained more ascorbic acid than the late maturing varieties. Pyke (83) presented data that indicated the ascorbic acid content of cabbage harvested in May and June contained approximately five times as much as that harvested July to October. Gould et al. (32) found that the ascorbic acid content of early varieties which they tested was nearly twice that of late varieties. Burrell et al. (12) reported that the same variety differed in amounts of ascorbic acid at different seasons and in different years, but the tendency was for the relative status of that variety in ascorbic acid content to be maintained. They found earliness, as judged by the proportion of crop harvested before July 6th, to be correlated with high ascorbic acid concentration.

Murphy (70) concluded that variations in the ascorbic acid content of the same variety of cabbage were influenced by environmental agents related to season more than by those associated with geographical location. In a study by Poole et al. (80) on 25 breeding lines they stated (p. 328): "Only six lines differed significantly in ascorbic acid content from season to season. In only one of these was the content higher in the fall than in the spring." Season affected head size mainly, whereas hereditary factors affected the variability in ascorbic acid between breeding lines. Allen et al. (1) noted that of the 14 varieties of cabbage grown in England the varieties maturing in the spring and early summer were, in general, richer in ascorbic acid than those maturing in other seasons of the year. Smith and Walker (92) found a tendency toward higher ascorbic acid content in the August harvest than in the July, September, and October harvests.

Three reports by Lampitt et al. (48, 50, 52) were in agreement that the average value for winter cabbage was approximately 0.6 milligram per gram and for spring cabbage, approximately 1 milligram. Lampitt et al. (54) found that the seasonal differences between spring and summer types of English varieties tended to disappear when those varieties were grown in South Africa in the summer of 1948. Janes (41) compared cabbage grown in Florida in two seasons at four levels of water supply and found that, with some exceptions, the January crop contained slightly higher concentrations of ascorbic acid than the April crop. In another study of Florida-grown vegetables Janes (40) reported differences in the ascorbic acid of cabbage from two cuttings made 10 to 14 days apart within the same season. In three of four cases the ascorbic acid decreased between the first and second cuttings.

A high concentration of ascorbic acid in the cabbage heads of three varieties was found by Hallsworth and Lewis (33) to be associated with a large amount of solar radiation for 7 days prior to harvesting at maturity. Diurnal variation was studied among seedlings analyzed at 9:30 A. M. and at 4:00 P. M. and no significant differences in ascorbic acid content were found (averages were 70.7 and 69.2 milligrams, respectively, for the two periods). Smith and Walker (92) could find no simple relation between the ascorbic acid content of varieties and conditions of temperature, length of day, and amount of light energy for a 20-day period before harvest.

Only a slight seasonal variation in ascorbic acid content was apparent for cabbage purchased during each of the 12 months of the year in which the foods served to Royal Canadian Air Force personnel were being studied by Branion et al. (9). The average value for the 579 assays was 59.2 milligrams.

IRRIGATION

One study was found in which the effects of irrigation on the amount of ascorbic acid in cabbage were indicated. Janes (41) reported experiments in which Florida-grown cabbage planted in each of two seasons was subjected to four levels of water supply as follows: no irrigation, occasional, medium, and frequent irrigations. The range in ascorbic acid concentrations for the two seasons was from 40.9 to 55.5 milligrams per 100 grams (603 to 669, dry weight). For the crop harvested in January, the weather was cool and the rainfall evenly spaced and no significant differences in ascorbic acid content due to irrigation were observed. However, for the crop harvested in April, even though the total rainfall was higher than in the first season, the weather was dry during the period of active growth of the cabbage plants. In this season, greater amounts of irrigation were reflected in larger heads and, in general, a decreased concentration of ascorbic acid per unit of weight.

FERTILIZER LEVEL

The studies reviewed indicated that the amount of ascorbic acid present in cabbage was influenced only slightly, if at all, by the fertilization of the soil. Janes (40) presented data for two varieties of cabbage grown at eight locations in Florida at three levels of fertilizer treatment (½, 1, and 1½ times the amount normally applied). He found no differences in ascorbic acid content associated with the fertilizer treatment. This investigator selected four locations for further study and found that at only one of these was the ascorbic acid content significantly affected by the fertilizer levels. In that case the higher concentration of the vitamin occurred in the cabbage receiving the one-half normal application of fertilizer.

In other work Janes (41) studied the effect of applying two side dressings of sodium nitrate to cabbage plants in comparison with no side dressings. The ascorbic acid content of the cabbage heads was not significantly affected for the crop harvested in January. However, for the crop harvested in April in which four side dressings of the sodium nitrate were compared to no side dressing, the addition of the nitrogen-containing fertilizer was associated with an increase in ascorbic acid content of the cabbage on a dry basis but no significant difference on a fresh basis. French and Abbott (30) found little effect on the ascorbic acid level of cabbage grown in Florida as a result of supplementation of the fertilizer with certain minor elements. Smith and Walker (92) reported highly significant increases in yield of cabbage associated with

fertilization of the soil, but non-significant variations in ascorbic acid content of the cabbage. On the other hand, Burrell et al. (12) found in fertilizer tests that high ascorbic acid cabbage was associated with a high nitrogen or a complete fertilizer.

MATURITY

Studies indicated that as the cabbage plant matures the concentration of ascorbic acid declines. Murphy (70) noted decreases in ascorbic acid with advancing maturity in cabbage, the opposite of the trend noted with tomatoes. Branion et al. (10) analyzed ten cabbages of each of four varieties and found a tendency for the ascorbic acid content to be lower in the more mature heads, as judged by the weight of the heads, than in the less mature ones. A progressive decline in ascorbic acid concentration from the seedling stage to the mature head was reported by Hallsworth and Lewis (33) for plants assayed at periods of 2, 4, 6, 8, 11, 15, 19, and 23 weeks after transplanting the seedlings. A high of 185.1 milligrams per 100 grams of tissue was shown at 2 weeks to a low of 56.5 milligrams at full maturity (23 weeks).

Barr and Newcomer (4) investigated the ascorbic acid content of diploid and tetraploid plants of the same genetic constitution at two stages of maturity. In the diploid plants the lower green leaves of the immature plant contained 32.30 milligrams and the green outer leaves of the mature plant, 28.45 milligrams. In the tetraploid plants, the leaves of the immature plant contained 130.40 milligrams and the leaves of the mature plant, 61.90 milligrams. Smith and Walker (92) did not find a correlation between maturity and vitamin C.

PARTS OF HEAD

Uneven distribution of ascorbic acid within the cabbage head has been reported by several workers. Green leaves tend to be higher in the vitamin C than white leaves and some parts of the head generally discarded in preparation for table use are rich in ascorbic acid. Sheets et al. (89) found that green leaf blades had one-half more ascorbic acid than bleached leaves (0.95 percent and 0.65 percent, respectively, on a dry basis). Smith and Walker (92) reported that the outer green leaves of cabbage contained more vitamin C than the white inner leaves. Barr and Newcomer (4) gave values of 94.30 milligrams for the heart, 28.45 milligrams for the green outer leaves, and 48.40 milligrams for samples of the whole head. Allen et al. (1) found the coarse outer

leaves were generally richer in ascorbic acid by about 50 percent than the edible portion of the head, and the white stalk was a more concentrated source of the vitamin than the edible leaves.

Beckley and Notley (5) found the outer green leaves to be richest in vitamin C, the core and the heart leaves next, followed by curled green leaves and by white leaves of the head. Smith et al. (91) in some preliminary work obtained average values of 88.1, 52.2, and 48.5 milligrams percent, respectively, for the core, inner tissue, and outer tissue. For further study they removed samples from various parts of the head with a special cutter similar to an apple corer. On the basis of 15 samples per head for several cabbages, they found average values of 31.3 milligrams percent for the outer quarter and 42.4 for the inner quarter not including the core. Noble and Worthington (73) reported that for four pairs of samples the heart contained approximately 60 percent more ascorbic acid than the leaves from the same head.

Data by Hallsworth and Lewis (33) on duplicate samples of cabbage taken by cork-borer at 45-degree intervals around the equatorial plane of the head of cabbage revealed negligible differences in ascorbic acid as long as the sampling was kept at the one plane. They observed that the leaf blade was higher in ascorbic acid than the midrib regardless of the part of the cabbage head from which the leaves were taken although the difference was most pronounced for the outermost leaves. They found the core to be richer in vitamin C than any other part of the plant (average, 116.6 milligrams). A progressive decline occurred through the heart leaves to the intermediate leaves followed by a rise in the outer leaves (77.5 milligrams). No regular trend in the ascorbic acid content from the base of the leaf toward the tip was observed. Lampitt et al. (48) found that outer green leaves and the stalk of cabbage were more concentrated sources of vitamin C than the inner leaves and, similarly, the leaf blades than the midribs.

Branion et al. (10) investigated cabbages of several varieties and found that the commercial trimmings (consisting of outer, coarse, green leaves generally removed by the grower) had the highest average amount (88.0 milligrams) of any of the parts of the head. The next highest (84.6 milligrams) was for the trimmings, including core, which are generally removed in the kitchen. The edible portion had the lowest average value (70.3 milligrams). For this edible portion of the head, the inner third had more ascorbic acid (74.0 milligrams) than either the outer or middle thirds (67.5 and 65.7 milligrams, respectively).

SIZE OF HEAD

Studies in which size of the head has been found to be a factor in ascorbic acid content have indicated that small heads are a more concentrated source of ascorbic acid than large heads. Floyd and Fraps (29) reported that small headed varieties of cabbage were especially high in vitamin C (130 milligrams per 100 grams). Poole et al. (80, p. 326) stated: "The smaller average head weight of the spring crop, 2.57 ± 0.07 pounds, compared with that of the fall crop, 3.70 ± 0.10 pounds, was accompanied by a higher average ascorbic acid content 0.553 ± 0.007 mg. In the fall the average content was 0.529 ± 0.007 mg. The differences between general means for the two variables are statistically significant at the 1 percent point, 1.13 ± 0.12 pounds for weight and 0.024 ± 0.009 mg. for ascorbic acid." Hallsworth and Lewis (33) analyzed cabbage of three varieties and found a decrease in ascorbic acid content as the weight of the heads increased. On the other hand, Smith and Walker (92), Burrell et al. (12), and Lampitt et al. (52) found no relationship between head weight and vitamin C potency.

STORAGE

The tendency was for vitamin C losses to increase with rising storage temperatures and with increasing lengths of time of storage. Gould et al. (32) studied cabbage stored at three different temperatures, 1 to 3°, 8 to 9°, and 21 to 23° C., for various lengths of time (0, 19, 31, 42, 56, 70, and 84 days) and found that the loss of ascorbic acid was slow but increased with higher temperatures. According to Mayfield and Richardson (60), storage for 6 months in the home basement vegetable room resulted in approximately 25 percent loss of ascorbic acid. Lampitt et al. (49) reported that heads of cabbage kept in a fairly cool room for 4 days retained all of their vitamin C; those cut in quarters and held at 3° C. for 5 days retained 83 percent; and those cut in quarters and held for 3 days at room temperature retained only 38 percent of their vitamin C.

In a study of methods suitable for temporary storage or display in a food store, Patton and Miller (79) found that heads of cabbage exposed to air at room temperature (about 80° F.) for 4 to 5 days retained approximately 85 percent of their ascorbic acid. Retentions of 90 percent or higher were found for cabbage stored by any of three other methods, namely, (a) refrigerated at approximately 50° F., (b) packed in crushed ice in a drained metal tray, (c) placed on crushed ice in an open display case.

CUTTING BY DIFFERENT METHODS

Ascorbic acid losses of varying severity occurred during the cutting of cabbage and the trend seemed to be toward greater losses as the amount of bruising of tissue was increased. Pyke (82) reported losses of 34 and 10 percent, respectively, for grated and for shredded cabbage but no significant loss for cabbage cut with a sharp knife. McMillan and Todhunter (59) determined vitamin C in cabbage cut with a knife and shredded with a shredder. There was relatively more dehydroascorbic acid in the shredded and more reduced ascorbic acid in that cut with a knife, whereas the total ascorbic acid was about equal in the two samples. Lampitt et al. (47) investigated the relation of mechanical breakage in the cells to ascorbic acid losses. Cabbage chopped with a meat grinder type of cutter for periods up to 30 minutes lost more ascorbic acid as the length of time of chopping was increased. Quinn et al. (84) found that use of a sharp knife or a household shredder for cutting cabbage made little difference in the ascorbic acid content of the cabbage when tested 20 minutes after cutting. McCay et al. (57) reported only a slight loss of ascorbic acid in cabbage (tested 30 minutes and 2 hours after cutting) for the material cut with a plastic knife, but marked losses when either a steel knife or a rotary chopper had been used. Data on large quantity preparation of coleslaw by Munsell et al. (62) indicated that cabbage lost more reduced ascorbic acid during mincing with a rotary chopper (52 percent loss) than during shredding (19 percent loss). On the basis of total ascorbic acid, however, the losses were small by either method of cutting (3 percent by mincing and 6 percent by shredding).

The juice expressed from a definite weight of cabbage with a hand-operated juicer contained 69 percent as much reduced ascorbic acid as the whole vegetable, according to Puffer et al. (81). For equal weights of cabbage and of cabbage juice, the juice contained a slightly higher concentration of vitamin C than the cabbage (34.3 and 32.9 milligrams, respectively).

HOLDING OF RAW CUT CABBAGE

Several studies indicated that the temperature at which cut cabbage was held was an important factor in vitamin C stability and that the use of low temperatures favored the retention of the vitamin in the food. Lampitt et al. (49) found that quarters of heads of cabbage held for as long as 5 days under refrigeration at 3° C. lost only a small amount of ascorbic acid, but quarter-heads kept at room temperature for periods up to 3 days lost vitamin C rapidly after the first day. In

another study (47), they reported that minced cabbage cut experimentally with meat grinder types of cutters lost ascorbic acid rapidly until a steady value was reached within 10 to 15 minutes, and remained at this level up to 30 hours if the cabbage was kept cold (15° C.). McMillan and Todhunter (59) reported that cut cabbage and shredded cabbage held for as long as 120 minutes showed a retention of 95 percent or more of the total original ascorbic acid. Samples of cabbage cut by three different methods were analyzed for ascorbic acid by Pyke (82) at intervals up to 3 hours. The vitamin C losses which occurred had taken place within 5 to 10 minutes of holding.

Holding either shredded or minced cabbage at room temperature for 3 hours after cutting the cabbage for institutional service of coleslaw resulted in no significant losses of either total or reduced ascorbic acid, according to Munsell et al. (62). A subsequent 22-hour storage period in the refrigerator resulted in an 8 percent total and 9 percent reduced ascorbic acid loss in the minced cabbage but no significant loss in the shredded cabbage. Schauss (88) reported a decrease of 59 percent of ascorbic acid in cabbage tested before and after preparation for serving raw in an institution where an hour or more usually elapsed between cutting of the cabbage and further preparation for service. Orent-Keiles et al. (77) found decreases of 6.1 to 33.4 percent in ascorbic acid of cabbage between the initial preparation of the shredded or quartered cabbage and the time of serving as coleslaw in an army mess.

The effect of pH during holding of an extract of cabbage prepared by pressing the juice from raw cabbage under high pressure, was determined by Kohman and Sanborn (44). At the natural pH of 6.71, the losses of ascorbic acid from the extract were large (81.8 percent by the end of 5 hours), but only small losses occurred (8.7 percent in 5 hours) in the extract adjusted to a pH of 3.72 with added hydrochloric acid. The juice expressed from cabbage with a household juicer by Puffer et al. (81) contained a smaller amount of reduced ascorbic acid after standing for 1 hour than when freshly prepared.

HOLDING OF RAW CUT CABBAGE TO WHICH DRESSINGS HAVE BEEN ADDED

Cut cabbage with added mayonnaise or French dressing retained slightly more ascorbic acid during holding for a few hours than without dressing. Clayton (17) reported the effect of mayonnaise on the oxidation of vitamin C. The loss of ascorbic acid from raw cabbage after 3, 5, and 24 hours of contact with cider vinegar mayonnaise was 58.7, 79.9, and 100 percent, respectively. Contact with an experimental mayonnaise made with distilled water instead of vinegar or

lemon juice resulted in 10.7, 17.7, and 69.1 percent loss, respectively, for the three periods of holding. In another series of tests, 2½ and 4¼ hours of contact with cider vinegar mayonnaise resulted in 67.8 and 69.2 percent ascorbic acid loss, respectively, whereas the same lengths of time with lemon juice mayonnaise (4 days old, at which time it contained no vitamin C) resulted in loss of 57.1 and 57.9 percent, respectively.

Quinn et al. (84) determined the ascorbic acid content of cabbage salads made in family size quantities with three kinds of dressing, i. e., French, vinegar mayonnaise, and lemon juice mayonnaise. The effects of storage at room temperature or in a refrigerator for 30 minutes and for 5 hours were compared. Approximately two-thirds or more of the vitamin C was conserved by any of the methods of holding, but the samples to which salad dressing had been added retained more of the vitamin than those held without the dressing. Either kind of mayonnaise was more effective than French dressing, but the lemon juice mayonnaise offered more protection to vitamin C than the vinegar mayonnaise. These effects were not accounted for by the amount of ascorbic acid in the lemon juice mayonnaise nor by the pH of the three kinds of dressing.

In a study of institutional food service, Munsell et al. (62) found that the losses of both total and reduced ascorbic acid in shredded and in minced cabbage with added French dressing were similar in a 3-hour holding period to the losses in the corresponding products without the dressing, whereas rather large further losses of reduced ascorbic acid (but only slight losses of total ascorbic acid) were noted during the 22-hour holding period in which the dressing was present.

Heller et al. (35) gave a value of 3.15 milligrams for an 85-gram serving of cafeteria-prepared coleslaw. The cabbage salad served in four college dining halls of the Pacific Northwest was reported by Fincke et al. (27) to have mean ascorbic acid values of 20.5, 26.1, 52.3, and 25.7 milligrams per serving, respectively, and a grand mean of 26.3 milligrams per serving. Storvick et al. (93) reported that the cabbage slaw served in certain college residence halls the three times it appeared on the menu contained an average of 40.7 milligrams per 100 grams. In a cooperative residence hall on another college campus, the ascorbic acid value of a dinner item described as "cabbage salad, with parsley" was reported by Dunkerley and Kramer (25) as 15.7 milligrams for the 38.4-gram serving. The vitamin C content of a 110-gram portion of salad containing carrot and cabbage as served for lunch in a restaurant, was found by Sarett et al. (87) to be 8 milligrams.

ASCORBIC ACID IN COOKED CABBAGE

COOKING IN DIFFERENT TYPES OF UTENSILS

Several investigators have compared the effects of cooking in two or more types of utensils on the retention (or loss) of ascorbic acid in cooked cabbage. Categories for classifying the cooking methods used are not well defined in the literature, but, generally speaking, the cooking by household or small quantity methods was done in one of the following kinds of utensils: (a) saucepan or kettle (with or without a lid), (b) waterless cooker, (c) household steamer, (d) pressure saucepan, (e) utensil for panning or frying, and (f) electronic device. For large quantity cookery, the following types were used: (a) stock pot (with or without a lid), (b) steamer (institutional type), (c) steam-jacketed kettle. A change in the type of utensil used made necessary certain modifications in procedure, for example, length of time of cooking, amount of water, or use of a lid, so that more than one variable was usually introduced.

Almost all of the studies in which cabbage was boiled in an open saucepan, kettle, or stock pot showed large losses of ascorbic acid. These losses were usually associated with high concentrations of ascorbic acid in the liquid drained from the cabbage. The use of a tightly covered saucepan or kettle (and a small amount of cooking water) resulted in higher retentions of ascorbic acid than for open pan cookery. Thus the proportion of water and the length of time in contact with the cabbage in a particular kind of utensil were important factors in vitamin C conservation.

Several studies have been reported in which the retentions of ascorbic acid in boiled drained cabbage were below 50 percent. Wellington and Tressler (102) found 22 percent retention in boiled shredded cabbage. Noble and Hanig (72) had a value of 26 percent for coarsely shredded cabbage boiled in an open kettle. Eheart and Sholes (26) gave 29.6 percent for cabbage cooked by the "old-fashioned" method (large amount of water and long time of cooking). Burrell and Ebright (13) reported a 70 percent loss of ascorbic acid with cooking water discarded (55.5 percent loss for cabbage served without draining). Hewston et al. (36) found retentions of 37.2 to 43.8 percent for two lots of green and one lot of white cabbage. Sutherland et al. (94) found approximately 40 percent retention for cabbage strips and 45 percent for wedges boiled in an open pan. A retention of 44.3 percent of the vitamin C was indicated by data of Krehl and Winters (45) for open pan cookery. The boiled cabbage prepared by Thomas et al. (96)

retained 42 percent of its ascorbic acid. Branion et al. (10) reported a 62 percent loss for cabbage boiled in 4-serving lots, but 72 percent loss when boiled in 100-serving lots. The data of Munsell et al. (62) on large quantity cookery indicated retentions of 28 or 30 percent for total ascorbic acid in quarters of cabbage boiled in water to cover and of 40 percent for coarsely cut cabbage with a minimum of water. Losses of 81 to 88 percent of the ascorbic acid were found by Orent-Keiles et al. (77) in boiled cabbage served in an army mess.

Other studies on boiled cabbage had data in which the retentions of the vitamin in boiled cabbage were above 50 percent. Ireson and Eheart (39) used water to cover the pieces of cabbage during boiling in an open kettle and had 53.67 percent retention of ascorbic acid in the vegetable. Krehl and Winters (45) found a 57.4 percent retention for cabbage boiled in a minimum of water in covered pan (which was higher than their figure for cabbage boiled in water to cover). Eheart and Sholes (26) presented average values of 54.7, 56.9, and 66.7 percent, respectively, for retentions of ascorbic acid in open kettle, closed kettle, and modified old-fashioned methods of cooking cabbage. Sutherland et al. (94) indicated approximately 53 percent retention for strips boiled in covered pan (in open pan with water to cover the retention was 40 percent). Noble and Hanig (72) had 66 percent of the ascorbic acid retained in coarsely shredded cabbage boiled in a tightly covered kettle. Ireson and Eheart (39) reported 83.56 percent retention of ascorbic acid in pieces of cabbage cooked in a minimum of water in a covered pan.

Van Duyne et al. (98) did not express their findings as percentages, but concentrations of 0.40 milligram per gram in boiled cabbage compared to 0.45 in the raw in 1948, and of 0.32 milligram for cooked and 0.39 for raw in 1949, indicated somewhat higher retentions of the vitamin than several other investigators have found. Small net losses were reported by Lampitt et al. (53) for vitamin C in cabbage cooked in a small amount of rapidly boiling water. These workers compared the ascorbic acid losses and the rate of rise of temperature in various positions within cabbage cooked in a covered pan with a small amount of boiling water. They used thermocouples located at four levels from top to bottom. One utensil of aluminum and another of enamel (similar but not identical in size) were used. Greater depth of the vegetable in the enamel pan and lower heat conductivity of that utensil resulted in slower heating and a somewhat greater loss of ascorbic acid than in the aluminum pan. The net losses of the vitamin by cooking in the aluminum and enamel pans were 2 and 14 percent, respectively.

Fewer reports have been made for other methods of cooking cabbage than in a saucepan or kettle. Brinkman et al. (11) and Krehl and Winters (45) found retentions of 61 and 68.4 percent, respectively, for cabbage cooked in the waterless cooker. Both of these values were higher than the respective workers had obtained for cabbage cooked in a saucepan.

Wellington and Tressler (102) used a household steamer and found retentions of ascorbic acid similar to those for boiled samples (24 percent for steamed and 22 percent for boiled cabbage). On the other hand, the steamed cabbage of Sutherland et al. (94) retained approximately 65 percent of its vitamin C, which was higher than for cabbage boiled in an open or in a covered pan. Lampitt et al. (48) reported a 65 percent retention for steamed cabbage compared to 40 percent for boiled cabbage. The steamed cabbage of Noble and Hanig (72) retained 68 percent of total ascorbic acid. This value was similar to that for cabbage boiled in tightly covered pan but markedly higher than for the samples cooked in open kettle.

Cabbage cooked in 100-serving lots in a low-pressure steamer, according to Branion et al. (10), lost an average of 70 percent of its ascorbic acid compared to a 72 percent loss by boiling. Munsell et al. (62) used two kinds of steamers in the large quantity preparation of cabbage. A retention of 58 percent of the ascorbic acid resulted from steaming quarters in an institutional type steamer and of 67 percent when the quarters were suspended over boiling water in a covered stock pot. Both values for steamed cabbage were markedly higher than the retentions in boiled cabbage. Daum et al. (24) indicated a loss of 40.9 percent of ascorbic acid for cabbage prepared on an institutional basis, but did not state the particular method of cooking.

Sutherland et al. (94) used steam-jacketed kettles for large quantity cookery of cabbage wedges and found average ascorbic acid retentions of 51 percent compared to 45 percent for similar samples boiled by a household method.

The effect of pressure saucepan cookery of cabbage on ascorbic acid retention was investigated by several workers who found values higher than 50 percent. Brinkman et al. (11) reported 53 percent retention by pressure cooking which was higher than by boiling; 65 percent by Sutherland et al. (94), which was the same as the retention by steaming and higher than by boiling in open or closed saucepan; 71 percent by Thomas et al. (96), which was higher than for boiled; 72 percent by Noble and Hanig (72), which was similar to the values by boiling in tightly covered kettle and by steaming but higher than by boiling

in open kettle; and 77.5 percent by Krehl and Winters (45), which exceeded the retentions by three other methods of cookery. Findings for pressure cooked cabbage by Van Duyne et al. (98) were not calculated on a percentage basis, but the retention by pressure cooking was slightly lower than by boiling for 1948 but no difference was apparent in 1949. Richardson and Mayfield (85) reported no loss in ascorbic acid due to pressure cooking for new cabbage, but for stored cabbage, a reduction from 0.470 milligram per gram raw to 0.279 milligram occurred during cooking in a pressure saucepan.

A cooking method in which the cabbage was designated as fried resulted in 48.4 percent retention of ascorbic acid, according to Eheart and Sholes (26). This value was lower than for any of the five methods compared except the old-fashioned. Wellington and Tressler (102) found 66 percent retention for panned cabbage compared to values below 25 percent for boiled or steamed cabbage. Patton et al. (78) found that panned cabbage, prepared by cooking finely cut cabbage in peanut oil to simulate a home-cooking practice in India, retained 75.6 percent of the vitamin C originally present. This retention was not significantly different from the value for boiled cabbage with no water to discard, but was markedly higher than the value of 23.8 percent for samples boiled in an excess of water.

The use of an electronic range was investigated by Thomas et al. (96) who found a retention of 59 percent of ascorbic acid for cabbage. This value was higher than for boiled samples but lower than for pressure cooked samples.

Percentages of ascorbic acid leached into the cooking water were generally high for cooking methods using a fairly large amount of water. For boiled cabbage, Wellington and Tressler (102) reported losses to the cooking water ranging from 53 to 66 percent for pieces of three sizes; Noble and Hanig (72), 50 percent by open kettle cookery; Ireson and Eheart (39), 37.36 percent; Thomas et al. (96), 37 percent; Munsell et al. (62), 26 to 33 percent for pieces of two sizes and two lengths of time of boiling; and Eheart and Sholes (26), 34.6, 21.9, and 14.7 percent for three modifications of the boiling method. Van Duyne et al. (98) reported concentrations of 0.21 and 0.16 milligram of ascorbic acid per milliliter for cooking water from cabbage boiled in a tightly covered saucepan. Sutherland et al. (94) stated that for the open saucepan the amounts of ascorbic acid were about equally distributed in the liquids and solids. For methods of cooking other than boiling, the data on the losses of ascorbic acid in the liquid drained from

the cabbage were reported as follows: loss to cooking water by steaming, Wellington and Tressler (102), 50 percent for shredded and 22 percent for quartered cabbage; Thomas et al. (96), 31 percent by electronic and 10 percent by pressure cooking; Van Duyne et al. (98), a lower concentration from pressure saucepan than from tightly covered pan one year but no difference the next year; and Sutherland et al. (94) and Noble and Hanig (72), a smaller loss to cooking water from tightly covered pan, steamer, or pressure saucepan than from open pan.

VARIATION IN AMOUNT OF WATER USED IN BOILING

The tendency was for losses of ascorbic acid to increase with increases in the proportion of water to vegetable used in boiling. Allen and Mapson (2) conducted experiments in which cabbage of more than one variety was cooked in several proportions of water to vegetable ranging from a minimum of 1.5 and maximum of 48 parts by weight of water to 1 part of shredded cabbage. As the amount of cooking water was increased the retentions of ascorbic acid in the vegetable decreased. The principal loss was by leaching into the cooking water and the remainder was by destruction of the vitamin. In this series of experiments the maximum retention of ascorbic acid in the vegetable was 48 percent. Lampitt et al. (48) used proportions of water to cabbage varying from 1:1 to 32:1 and found slightly better ascorbic acid retentions with the smaller than with the larger quantities of water. The range of retentions was 32 to 52 percent.

In an experiment using the same initial amount of water for boiling shredded fresh cabbage, Allen and Mapson (2) found that samples boiled vigorously, thereby resulting in a small final volume of cooking liquor, retained more ascorbic acid in the vegetable than the cabbage simmered gently and which therefore had a larger volume of cooking water at the end.

Patton et al. (78) compared the effect of two amounts of water, 1200 and 250 milliliters for 400 grams of shredded cabbage, and found 23.8 percent retention with the larger amount and 81.6 percent with the smaller amount of water. No liquid remained after cooking for the one method, but for the other method, the cooking liquid from a 100-gram portion of cooked cabbage contained 16.9 milligrams of ascorbic acid.

Krehl and Winters (45) had findings of 57.4 percent retention by using a small amount of water (½ cup to 500 grams of cabbage) compared to 44.3 percent retention for cabbage boiled in water to cover. Olliver (75) did experiments in which quarters of heads were boiled in various amounts of water in an uncovered enamel saucepan for 30

minutes. The ratios of water to cabbage used were 4, 4, 5, 9, 11, 13, and 14 to 1 and the corresponding percentages of retention of ascorbic acid were 31, 36, 35, 24, 15, 29, and 26. The author indicated that a smaller proportion of water than 4 to 1 was not practicable for cooking quartered cabbage. Lampitt et al. (51), however, cooked quarters of cabbage in 2, 2½, 6, and 11 parts of water to 1 part of vegetable and found retentions of 45, 39, 38, and 34 percent, respectively. With shredded cabbage in two of the proportions, 2:1 and 6:1, the retentions of ascorbic acid in the cooked vegetable were 49 and 22.5 percent, respectively.

In institution cooking, Munsell et al. (62) found the ascorbic acid losses in coarsely cut cabbage boiled in a minimum of water (12 pounds of water to 20 pounds of cabbage) to be 60 percent for total and 65 percent for reduced ascorbic acid. These losses were somewhat less extreme than those of 70 percent or more for quartered cabbage cooked in enough water to cover the vegetable.

COOKING AT DIFFERENT TEMPERATURES

McIntosh and Jones (58) cooked various vegetables at 0, 5, 10, 15, and 20 pounds pressure in a family-size, stainless steel, pressure saucepan equipped with special weights and gauges. They stated that in cabbage the ascorbic acid destruction varied from 10 to 16 percent and appeared to be independent of the pressure used. In a comparison of cooking at atmospheric and 15 pounds pressure, the cabbage cooked in a small amount of water at atmospheric pressure had an average retention of 87.1 percent in the vegetable itself and 1.6 percent in the liquid, whereas that cooked at 15 pounds pressure had a retention of 78.7 percent in the vegetable and 8.2 percent in the liquid.

Lampitt et al. (48) compared the practice of adding the raw vegetable all at once to the boiling water, in which case the temperature of the water was said to go as low as 60° C., to the practice of adding the raw vegetable so slowly that the water remained at the boiling point. The results were slightly in favor of the gradual addition of the vegetable as shown by a retention of 42 percent of the vitamin in the vegetable and 42 percent extracted into the cooking water, whereas by the rapid addition the retention was 38 percent and the solution was 36 percent. Gould et al. (32) found that approximately one-fourth of the ascorbic acid was lost in the interval between addition of cabbage to boiling water and the time at which the water returned to the boiling point. During subsequent intervals the destruction of ascorbic acid was small, but considerable solution in the cooking water took place.

A report by Olliver (75) in which simmering and boiling were compared, indicated that more ascorbic acid was lost by simmering cabbage for 30 minutes (70 percent loss) than by boiling to the same degree of doneness, which required 20 minutes of cooking (61 percent loss). Olliver (75) also compared normal steaming of cabbage for 30 minutes with placing the vegetable in the steamer 2 minutes before the water boiled. The percentages of vitamin C lost from the cabbage by the two methods were 48 and 65 percent, respectively, indicating greater loss of the vitamin by the second procedure. Lampitt et al. (48) carried out experiments similar to those of Olliver but found no appreciable difference in vitamin C losses by the two procedures.

SIZE OF PIECES

The size of pieces was generally found to be a factor in the retention of vitamin C in cooked cabbage. Large pieces retained more of the vitamin during cooking than small pieces. Wellington and Tressler (102) reported on ascorbic acid among 360-gram lots of cabbage that had been cut in shreds, in strips, and in quarters, and boiled to the "done" stage in 1800 milliliters of water. The shreds retained 22 percent; the strips, 32 percent; and the quarters, 38 percent of the amount in the raw cabbage. Other lots of the shreds and quarters were steamed, and the retention in the shreds was 24 percent as compared to 58 percent for the quarters.

Cutting cabbage in wedges resulted in greater retention of ascorbic acid than cutting in strips when both were cooked by the open saucepan method, according to Sutherland et al. (94). On the other hand, the data by Lampitt et al. (51) for quartered and for shredded cabbage at two ratios of water to vegetable indicated greater retention in quarters than in shreds when a 6 to 1 proportion was used, but little difference at a 2 to 1 ratio. Noble and Worthington (73) found retentions of approximately one-third for sections cut 2⅛ inches in thickness and for coarsely shredded cabbage cooked by boiling. The cooking water in either case contained about one-half of the ascorbic acid originally present.

LENGTH OF TIME OF COOKING

The findings indicated that with some exceptions, as the length of time of cooking cabbage was extended beyond that necessary to reach the "done" stage there was a decrease in the retention of ascorbic acid. In line with this trend was the report by Murphy (69) in which retentions of 54, 44, and 33 percent, respectively, were obtained for 30-minute, 1-hour, and 2-hour periods of boiling for quartered sections of

cabbage in covered utensils. Hewston et al. (36) found smaller retentions for cabbage boiled 60 minutes (range, 18.3 to 30.0 percent) than for the control samples boiled 10 minutes (range, 37.2 to 43.8 percent retention).

In large quantity cookery, Munsell et al. (62) compared cabbage boiled for 2 hours with that boiled for 20 minutes. In the 2-hour period the losses were 82 and 84 percent, respectively, for total and reduced ascorbic acid, whereas the values for the shorter time were 72 and 75 percent. The amount of vitamin C in the cooking water was slightly lower for the long-time method (27 percent, total; 25 percent, reduced form) than for the short-time method (33 percent, total; 30 percent, reduced form).

Cabbage steamed for 30, 40, or 60 minutes at either a rapid or a slow rate, retained less than 50 percent of its original vitamin C content, according to Allen and Mapson (2). The amount of vitamin C retained was inversely related to the length of the steaming period and was generally higher with rapid heating than with slow heating for the same length of time. Losses of the vitamin during steaming were principally the result of destruction of the vitamin rather than of leaching into the water.

Lampitt et al. (53) reported experiments in which cooking water drained from cabbage boiled for 20 minutes in a 10 to 1 proportion of water was cooled for 2 hours and reheated on a water bath to 88° C. Tests for ascorbic acid at 5-minute intervals indicated a gradual loss of the vitamin as the time of heating was extended. At the end of 20 minutes of heating, 42 percent of the ascorbic acid present in the freshly drained cooking water was retained. The authors suggested that since the ascorbic acid oxidase would have been inactivated, the destruction must have been catalyzed either by copper present in the water or by a heat-stable factor extracted from the vegetable.

On the other hand, Gould et al. (32) found little difference in the ascorbic acid content of cabbage boiled 12 minutes compared to samples cooked to a desirable stage of doneness in 6 minutes. Van Duyne et al. (98) reported that in a pressure saucepan by extending the time to half again as long under pressure as for cooking to "just tender" (1.5 minutes instead of 1 minute) resulted in no significant change in ascorbic acid retention either in the cooked cabbage or in the cooking water.

ADDITION OF SALT

The reports are not in agreement as to the effect of the addition of table salt to cabbage during cooking. Hoygaard and Rasmussen (38) boiled cabbage for 20 minutes in distilled water with and without added

salt. More ascorbic acid was conserved in the vegetable (54.0 percent) but less in the cooking liquid (20.5 percent) by the use of distilled water alone than by the addition of 1 percent sodium chloride (32.5 percent in the cabbage and 56.0 percent in the liquid). Olliver (75) found that in boiled green vegetables, including cabbage, the addition of salt did not have a significant effect on ascorbic acid loss.

ADDITION OF SODA

The few studies in which the effect of adding soda has been determined have indicated only slight or no losses of ascorbic acid associated with the use of small amounts of soda in cooking cabbage. Olliver (74) investigated the use of sodium bicarbonate or sodium carbonate in cooking water of cabbage and Brussels sprouts and concluded that the effect of soda was negligible in comparison with the differences due to methods of cooking and length of cooking time. Allen and Mapson (2) found that cabbage retained 22 percent of the vitamin in the cooked vegetable and 56 percent in the cooking water when boiled in 4 parts by weight of tap water. Additions of baking soda up to 0.60 percent (with final pH of cooking water as high as 8.8) had no adverse effect on the percentage of vitamin C retained in the vegetable. At all concentrations of sodium bicarbonate tested and with tap water alone, the amount of ascorbic acid leached into the cooking water was more than twice the amount retained in the vegetable.

Allen and Mapson (2) used the cooking water from boiled cabbage for further tests. In one series, two different amounts of sodium bicarbonate were added and samples for analysis were taken after 0, 10, and 20 minutes of boiling. In the second series, the pH values of the cooking water were adjusted with soda to values ranging from 6.9 to 8.7 and specific amounts of pure ascorbic acid were added. After various lengths of time of boiling, the liquid was tested for ascorbic acid. The workers concluded that although interfering substances were formed at the high pH values, destruction of ascorbic acid was no greater with the addition of soda to the water than with plain tap water.

HOLDING OF COOKED CABBAGE

Losses of ascorbic acid have been shown to occur in cabbage during holding at refrigerator temperatures and during holding by various means to keep the vegetable hot for service after cooking. Gould et al. (32) reported that cooked cabbage stored in a refrigerator at 1 to 3° C. lost approximately one-fourth of the ascorbic acid in 24 hours and

about one-half in 48 hours, Lampitt et al. (48) concluded that approximately one-half of the vitamin C present in cooked cabbage was lost during 1 to 2 hours of holding to keep it warm for serving.

Holding of cooked cabbage to keep it warm for institutional food service, according to Daum et al. (24), resulted in a 7.6 percent loss of ascorbic acid in 15 minutes and 23 percent by the end of an hour. Losses of 11 percent for total ascorbic acid and 15 percent for the reduced form were reported by Munsell et al. (62) as the result of holding boiled quarters of cabbage in the cooking liquid on a warm part of the stove for 75 minutes and additional holding over steam for another 75-minute period. Schauss (88) found that cooked cabbage held on a steam table for 30 minutes had decreased in ascorbic acid from 25 milligrams to 17 milligrams. The loss due to both cooking and holding was 64 percent.

Branion et al. (10) reported progressive losses of ascorbic acid as either boiled or steamed cabbage prepared in 100-serving lots was held on the steam table for increasing lengths of time (15, 30, 45, 60, 90, and 120 minutes). For the boiled cabbage, the percentage of loss during cooking had been 72 percent and reached 92 percent by the end of 120 minutes of holding on the steam table. For the steamed cabbage, the loss due to cooking was 70 percent and amounted to 94 percent within the 2-hour holding period. Cabbage prepared on a 4-serving basis lost 62 percent in cooking and the total loss was 81 percent after 1 hour on the steam table. Sutherland et al. (94) reported that the retention of ascorbic acid in cooked cabbage wedges held over steam for 1½ hours was decreased from 51 percent after cooking to 25 percent after holding. On the other hand, Nagel and Harris (71) found no losses in ascorbic acid beyond those occurring during cooking for restaurant-prepared red cabbage held on a steam table.

The liquid drained from cooked cabbage was stored by Sutherland et al. (94) in a refrigerator for 2 days and tested for vitamin C content after being brought to a boil. Fifty percent of the vitamin present before storage had been lost during storage and reheating. No further loss of vitamin C occurred in a 15-minute boiling period. Lampitt et al. (53) found the retention of ascorbic acid in the cooking water drained from boiled cabbage had dropped from 100 percent to 76 percent during 2 hours at room temperature. The cooking water was then heated over a water bath to 88° C. and samples were taken at 5-minute intervals. By the end of 20 minutes of heating the retention was 42 percent.

COMBINATION OF FACTORS

As was the case with several studies reported under raw cabbage, a number of reports on cooked cabbage could not be classified under such specific headings as cooking by different methods, amount of water, and holding, because the influence of a single factor could not be isolated. Those reports are reviewed in this section.

Orent-Keiles et al. (77) found losses of more than 80 percent (range, 80.8 to 87.6) to have occurred during preliminary preparation, cooking, and holding for service of boiled cabbage in an army mess. Nagel and Harris (71) investigated restaurant food and reported a 95 percent loss of the vitamin C in red cabbage cooked with sugar and vinegar for 60 minutes. Jenkins (42) reported values for samples of cooked cabbage collected from households in one university town and in two industrial cities of England. On the basis of 30 samples secured during September, 1943, the average ascorbic acid value was 13 milligrams (range, 3 to 38). For the 14 samples collected in April, 1944, the ascorbic acid content was higher than in the previous period, average 35 milligrams (range, 7 to 63).

Students eating at a college dining hall and participating in a dietary study were served cooked cabbage that had a mean reduced ascorbic acid value of 22.0 milligrams, according to Storvick et al. (93). The range of values for the four times served was from 11.2 to 28.2 milligrams. The raw cabbage served at one meal had a concentration of 70.8 milligrams. Fincke et al. (27) also studied the ascorbic acid content of foods as served in college dining halls. They reported a value of 11.6 milligrams per serving of cooked cabbage for the one time it appeared on the menu at one school, and a mean of 11.0 milligrams (range, 5.6 to 15.9) for the five times it was served at another school.

Cooked cabbage prepared by an institutional method was found by Schauss (88) to contain 25 milligrams of ascorbic acid in contrast to 48 milligrams before cooking. Waagen and Pett (99), in a study of sources of vitamin C in the foods of Alberta, Canada, reported an average of 20 milligrams for two samples of late green cabbage after cooking, compared to a value of 30 milligrams when raw. According to Murphy (69), cabbage which contained 0.32 milligram of reduced ascorbic acid per gram when raw retained 34 percent of the vitamin after roasting with beef for 1 hour and 55 minutes.

THIAMINE IN RAW AND COOKED CABBAGE

In a number of studies the thiamine values of cabbage were determined concurrently with those of ascorbic acid. In these instances the factors studied in relation to the one vitamin were also studied in relation to the other. However, the number of reports on ascorbic acid is much larger than on thiamine or any of the other vitamins. This might be anticipated in view of the fact that cabbage is a better dietary source of ascorbic acid than of any of the other vitamins.

The reports found in the literature which gave general information concerning the thiamine content of raw cabbage had average values ranging from 25 to 142 micrograms per 100 grams. Cabbage was classified as a poor source of thiamine by Booher and Hartzler (7) who reported an average of 81 micrograms. Lane et al. (55) noted 37 micrograms for the raw edible portion and 36 micrograms for the as purchased portion. Danish Ballhead cabbage grown in Manitoba was found by Connolly et al. (19) to contain an average of 33 micrograms (range, 30 to 37 micrograms) of thiamine for the four samples tested. Thiamine values were given by Munsell et al. (63, 64, 65, 66, 67, 68) for cabbages secured in various countries of Central America. The particular country and the composition of the samples were as follows, expressed as milligrams of thiamine per 100 grams: (a) Honduras, .053, .052, and .051; (b) Guatemala, .078, .032, .078, and for purple cabbage, .077; (c) El Salvador, .035, and .042; (d) Nicaragua, .025; (e) Costa Rica, .055, .029, and for purple cabbage, .142; (f) Guatemala, for purple cabbage, .076. Cabbage grown in one location in Mexico was found by Cravioto B. et al. (21) to contain 0.11 milligram. Cheldelin and Williams (14) reported a thiamine value of 1.4 micrograms per gram (17 micrograms, dry basis) for one sample of cabbage purchased in a Texas market. The average for cabbage grown in Florida, according to French et al. (31), was 0.033 milligram. Red cabbage had an average of 0.044 milligram. Krehl and Winters (45) used cabbage that contained 0.062 milligram of thiamine (0.90 milligram, dry basis). The strips and wedges of raw cabbage analyzed by Sutherland et al. (94) had average values of 46, 54, and 58 micrograms.

The effect of variety on thiamine content was reported by Pyke (83) for 23 varieties tested. The range was from 10 to 46 International units. Those varieties maturing in June contained a range of 13 to 26 units; in July, 10 to 17; and in October, 15 to 46.

Reports indicated that cabbage may be stored from 4 to 6 months without any appreciable loss in thiamine content. Mayfield and Richardson (60) found that samples of the Danish Ballhead variety lost

very little thiamine during storage for 6 months in a home basement vegetable room. Manitoba-grown cabbage used in a storage study by Connolly et al. (19) had a potency of 31 micrograms of thiamine, but after storage in a moist place at 32° to 40° F. for 121 days the value was 35 micrograms.

Cabbage cut with a mechanical vegetable slicer contained the same amount of thiamine (0.068 milligram) as the cabbage minced with a rotary chopper, according to Munsell et al. (62). Holding the raw cabbage for 3 hours at room temperature and an additional 22 hours in the refrigerator resulted in less than 10 percent loss of thiamine. Addition of French dressing to the shredded or to the minced cabbage prior to holding had little effect on thiamine stability.

The effects of various cooking methods were studied and retentions of thiamine for boiled cabbage of higher than 35 percent were found. The boiled fresh cabbage of Connolly et al. (19) retained 37 percent of the thiamine in the cooked vegetable and 36 percent in the cooking liquid. Similar cabbage stored for 4 months had decreased in weight but after boiling had retained 51 percent of the thiamine in the cooked vegetable and 44 percent in the liquid. Sutherland et al. (94) reported 43 percent retention in wedges and approximately the same for strips boiled in an open saucepan. Thomas et al. (96) noted 53 percent in the cabbage and 52 percent in the liquid after boiling in water to cover. The use of water to cover the cabbage by Krehl and Winters (45) resulted in a saving of 62.4 percent of the thiamine compared to 70.2 percent with a small amount of water. Waterless cooking conserved 89.2 percent of the thiamine. Sutherland et al. (94) had approximately 80 percent retention by using a tightly covered saucepan and nearly 90 percent by steaming.

The use of a pressure cooker resulted in the following retentions of thiamine: by Krehl and Winters (45), 69.1 percent; by Sutherland et al. (94), approximately 80 percent; by Thomas et al. (96), 88 percent in the solids and 3 percent in the liquid. An electronic range was also used by Thomas et al. (96) who reported that 62 percent of the thiamine was retained in the cooked cabbage and 42 percent in the liquid. The amount in the solids was higher than by boiling but lower than by pressure cooking.

On a large quantity basis, Munsell et al. (62) found that 43 percent of the thiamine was retained for cabbage wedges cooked in water to cover, whereas the values were 85 and 88 percent, respectively, for two methods of steaming. The 46 percent retention of thiamine

reported by Sutherland et al. (94) for cabbage wedges cooked in a steam-jacketed kettle was slightly higher than the retention during boiling by a household method.

High retention of thiamine was reported by McIntosh and Jones (58) for cabbage cooked at atmospheric pressure (87.2 percent in cooked vegetable and 1.7 percent in the liquid) and for similar cabbage cooked at 15 pounds pressure (93.9 and 6.4 percent in vegetable and in liquid, respectively).

The use of a minimum amount of water for cooking shredded cabbage for institutional food service by Munsell et al. (62) resulted in a saving of 66 percent of thiamine. The figure was 43 percent for quarters of the same lot of cabbage boiled in sufficient water to cover.

Increasing the boiling period from 20 minutes to 2 hours for cabbage cut in quarters and covered with water resulted in a decrease of thiamine from 41 to 33 percent in the cooked vegetable and from 72 to 68 percent in the cooking water, according to Munsell et al. (62).

Sutherland et al. (94) found that holding of cooked wedges over steam brought about an additional 6 percent loss in thiamine beyond the amount lost during cooking; less than half (40 percent) of the original thiamine content was present in the food as served. Nagel and Harris (71), in a study on the effect of restaurant cooking and service on the vitamin content of foods, reported a loss of 82 percent of the thiamine from red cabbage cooked for 60 minutes. The loss was increased to 86 percent when the cooked cabbage was held on the steam table for 3 hours. Munsell et al. (62) found that an additional loss of 6 percent of the thiamine content of boiled cabbage was brought about by holding quarters of cabbage in the cooking liquid for 75 minutes on a warm part of the stove, then draining and holding the drained quarters for 75 minutes on a steam table.

Other workers gave general information on the thiamine content of cabbage as served. Heller et al. (35) reported that the amount of thiamine in an 85-gram portion of cafeteria-prepared coleslaw was 50 micrograms. The thiamine content of a restaurant serving of carrot and cabbage salad was 10 micrograms for the 110-gram portion, according to Sarett et al. (87). In a study of typical hospital diets, Shetlar et al. (90) reported for steamed cabbage an average of 0.0500 milligram of thiamine per 100 grams the two times it appeared on the menu.

RIBOFLAVIN IN RAW AND COOKED CABBAGE

The riboflavin content of cabbage was determined by several workers. The average values for raw cabbage reported on a fresh weight basis varied from 25 to 85 micrograms per 100 grams. Munsell (61) found 38 micrograms for green cabbage purchased on the winter market. The Florida-grown green cabbage assayed by French et al. (31) had 0.040 milligram and the red cabbage, 0.052 milligram of riboflavin. Hodson (37) reported 0.44 and 0.66 microgram per gram (5.8 and 7.1, dry basis) for two lots of cabbage. A sample from Texas reported by Cheldelin and Williams (14, 15) and Cheldelin et al. (16) contained 0.57 microgram per gram.

Sutherland et al. (94) analyzed the strips and wedges of cabbage used in two methods of cooking and found average riboflavin values of 27, 32, and 44 micrograms. Krehl and Winters (45) used cabbage that contained an average of 0.057 milligram per 100 grams (0.83, dry basis). The two lots of green cabbage used for cooking by Hewston et al. (36) had 1.717 and 3.640 milligrams, dry basis (values reported only on dry basis).

Fresh cabbage grown in Mexico contained 0.06 milligram of riboflavin, moist basis, according to Cravioto B. et al. (21). The cabbage grown or purchased in various Central American countries and reported by Munsell et al. (63, 64, 65, 66, 67, 68) had the following riboflavin contents in milligrams per 100 grams: (a) Honduras, .038, .048, and .043; (b) Guatemala, .078, .036, .040, and for purple cabbage, .045; (c) El Salvador, .038 and .037; (d) Nicaragua, .025; (e) Costa Rica, .047, .033, and for purple cabbage, .085; (f) Guatemala, for purple cabbage, .031.

Munsell et al. (62) investigated several factors affecting riboflavin content of cabbage during preparation on a large quantity basis. The shredded cabbage of Copenhagen variety averaged 0.041 milligram and the minced cabbage of Charleston Wakefield variety had 0.040 milligram of riboflavin per 100 grams. Holding the raw shredded or the minced cabbage at room temperature for 3 hours or for a 22-hour additional storage period in the refrigerator, brought about either no loss or an apparent gain in riboflavin content. Differences due to the presence or absence of French dressing during holding were slight. Two references in which the riboflavin concentrations of salad or coleslaw as served were reported were the following: Sarett et al. (87), 27 micrograms in 110-gram portions of carrot and cabbage salad as served in a restaurant and Heller et al. (35) 30 micrograms in an 85-gram serving of coleslaw prepared for cafeteria service.

The method used in cooking cabbage has been shown to have an effect on the amount of riboflavin retained in cooked cabbage. For boiled cabbage as done by household methods, the retentions ranged from 42 to more than 80 percent. Sutherland et al. (94) reported 42 percent retention for cabbage wedges boiled in an open saucepan and about 47 percent for strips of cabbage. Hewston et al. (36) found retentions of 48.0 and 69.0 percent, respectively, for two lots of green cabbage boiled for 10 minutes in uncovered utensils. Krehl and Winters (45) reported a conservation of 48.3 percent of the riboflavin for cabbage cooked in open pan with water to cover and of 70.4 percent when cooked in a minimum of water in a covered pan. The boiled cabbage reported by Thomas et al. (96) contained 61 percent of the amount originally present. Sutherland et al. (94) had slightly more than 80 percent retention in cabbage strips cooked in a tightly covered saucepan. On a large quantity basis, Munsell et al. (62) found retentions of 47 and 50 percent, respectively, for two lots of boiled cabbage. Assays of the cooking water from the first lot of cabbage indicated that 67 percent of the riboflavin was present in the water.

The use of a waterless cooker by Krehl and Winters (45) was associated with a conservation of 84.1 percent of the riboflavin. Cheldelin and Williams (15) and Cheldelin et al. (16) found a 16 percent loss due to steaming of cabbage by a household method. Sutherland et al. (94) noted a retention of more than 90 percent for steamed cabbage strips and of about 85 percent for strips cooked under pressure. Krehl and Winters (45) reported that approximately the same retention (84.9 percent) was obtained in the pressure saucepan as in the waterless cooker (84.1). Thomas et al. (96) reported 95 percent retention of riboflavin for pressure-saucepan cookery of cabbage, which was a higher value than for boiled cabbage (61 percent) or for the vegetable prepared on an electronic range (69 percent).

No loss of riboflavin was found by Munsell et al. (62) for cabbage steamed by two different methods on a large quantity basis. Sutherland et al. (94) used a steam-jacketed kettle for cooking cabbage wedges on an institutional basis and reported a 58 percent retention of riboflavin compared to 42 percent for the household method of open pan cookery.

Two different amounts of water were used by Munsell et al. (62) for boiling 20-pound lots of cabbage. They found greater conservation of riboflavin with a small proportion of water (71 percent retention) than by the use of water to cover the vegetable (50 percent retention).

Boiling of cabbage for 60 minutes rather than 10 minutes had no consistent effect on the retention of riboflavin, according to data by Hewston et al. (36) for home cooking procedures. Munsell et al. (62) studied the effects of boiling for 20 minutes and for 2 hours on an institutional basis and found riboflavin retentions of 47 and 39 percent, respectively. The proportions of the vitamin retained in the cooking water during the two cooking periods were 67 and 78 percent, respectively.

Decreases in riboflavin due to holding the cooked cabbage on a steam table for serving were noted in two studies. Sutherland et al. (94) reported a change from 58 percent retention after cooking to 46 percent after holding for cabbage wedges held 1½ hours. Munsell et al. (62) found losses of 8 percent in riboflavin content associated with keeping quarters of cabbage hot during 2½ hours of holding.

NIACIN IN RAW AND COOKED CABBAGE

The average values reported for niacin content of raw cabbage varied from 118 to 526 micrograms per 100 grams. Cheldelin and Williams (14, 15) and Cheldelin et al. (16) reported 210 micrograms for a Texas sample. Russell et al. (86) found values of 118 and 264 micrograms for cabbage purchased in New Jersey. Florida-grown cabbage analyzed by French et al. (31) had 0.26 milligram and the red cabbage had 0.27 milligram. Tepley et al. (95) reported 0.29 milligram percent (4.46, dry basis) for cabbage. Kodicek (43) gave a value of 3 micrograms per gram for apparent nicotinic acid of cabbage.

A sample of cabbage grown in Mexico and analyzed by Cravioto B. et al. (21) had 0.40 milligram of niacin per 100 grams. Samples from several Central American countries assayed by Munsell et al. (63, 64, 65, 66, 67, 68) had the following concentrations of niacin (milligrams per 100 grams): (a) Honduras, .336, .335, and .374; (b) Guatemala, .526, .224, .220, and for purple cabbage, .335; (c) El Salvador, .206 and .216; (d) Nicaragua, .160; (e) Costa Rica, .178, .174, and for purple cabbage, .384; (f) Guatemala, for purple cabbage, .247.

Raw cabbage used by Krehl and Winters (45) for cooking studies contained 0.260 milligram of niacin (3.77, dry basis). The freshly shredded cabbage of Copenhagen variety used by Munsell et al. (62) had an average content of 0.29 milligram and the freshly minced cabbage of Charleston Wakefield variety had 0.33 milligram of niacin. The concentration of niacin in the raw green cabbage used by Hewston et al. (36) for cooking by home procedures was 3.13 milligrams per 100 grams, dry weight.

Data collected in large quantity food preparation by Munsell et al. (62) indicated a gain of this nutrient in both the shredded and the minced cabbage either with or without French dressing during holding at room temperature for 3 hours and subsequently in a refrigerator for 22 hours. The niacin value for a 110-gram serving of carrot and cabbage salad as served in a restaurant was reported by Sarett et al. (87) as 210 micrograms. Heller et al. (35) found 0.33 milligram of niacin in an 85-gram portion of coleslaw as prepared in a cafeteria.

The effect of cooking by different methods on the niacin concentration of cabbage was studied by a few workers. Retentions of the vitamin varied from about one-half to over three-fourths of the amount present in raw cabbage. For boiled cabbage, Krehl and Winters (45) found 48.3 percent retention of niacin when water to cover the vegetable was used, compared to 70.4 percent with a minimum of water. Russell et al. (86) assayed three samples of boiled cabbage cooked in a small amount of water and found a range of 69.7 to 79.3 percent retention in the cabbage. The cooking water from one sample contained 4.1 percent of the vitamin.

The use of a waterless cooker conserved 86.1 percent of the niacin, according to Krehl and Winters (45). This figure was higher than for two methods of boiling or for pressure cooking. Steaming cabbage by a household method, as reported by Cheldelin and Williams (15) and Cheldelin et al. (16), resulted in 19 percent loss of niacin. Krehl and Winters (45) found that cooking in a pressure saucepan was associated with a saving of 74.9 percent of the niacin.

Very little difference in percentages of niacin retention in cabbage resulted from boiling for 60 minutes (44.2 percent) compared to boiling for 10 minutes (46.4 percent) in studies by Hewston et al. (36).

OTHER VITAMINS IN RAW AND COOKED CABBAGE

The pantothenic acid content of the edible portion of raw cabbage, according to Cheldelin and Williams (15) and Cheldelin et al. (16), was 180 micrograms per 100 grams. The value after steaming was 130 micrograms. Sarett et al. (87) analyzed carrot and cabbage salad as served in a restaurant and found a content of 310 micrograms in a 110-gram serving.

The amount of pyridoxine in a sample of fresh cabbage was reported by Cheldelin and Williams (14) to be 1.2 micrograms per gram (14 micrograms, dry weight). Lampen et al. (46) found cabbage to be a poor source of biotin. The water extract contained 62 millimicrograms per gram of dry matter. Cheldelin et al. (16)

reported that there was no loss of biotin during the steaming of cabbage, 2.4 micrograms per 100 grams before cooking and 2.8 micrograms after cooking. These same workers reported on the inositol (95 milligrams per 100 grams) and folic acid content (65 micrograms per 100 grams) of cabbage. They found a 35 percent loss of inositol and a 92 percent loss of folic acid during steaming. Findings of Olsen et al. (76) indicated that the folic acid (B_c) value for a sample of fresh cabbage, using **S. faecalis** as the test organism was 12 micrograms per 100 grams. Toepfer et al. (97) used **L. casei** and **S. faecalis** as test organisms and presented data on the total and the free folic acid content of cabbage. Average values for total folic acid of summer cabbage ranged from 0.0064 to 0.0746 milligram and the samples of red cabbage had an average of 0.0171 milligram. The free folic acid values with the two kinds of organisms were 0.0028 and 0.0034 milligrams for summer cabbage.

Lindheimer et al. (56) used three color tests to estimate the citrin (vitamin P) concentration in cabbage and obtained values ranging from 0.003 to 0.01 milligram of citrin (as eriodictin) per gram of material. Bacharach and Coates (3) found that October cabbage contained more vitamin P than April cabbage, 100 provisional units per 100 grams as compared to 60.

Several studies have been made of the amount of carotene (or vitamin A value) in cabbage and the effects of various handling and cooking procedures on this nutrient. Those studies in which vitamin A values were reported in International units had the following data for raw cabbage: approximately 40 International units per 100 grams for Red Dutch variety and up to 100 for summer cabbage by Booher and Marsh (8); 300 for a sample designated as frozen cabbage by Fitzgerald and Fellers (28); average of 500 (range, 200 to 2,000) for 23 varieties tested by Pyke (83); and 8.8 per gram by Coward and Morgan (20).

Several investigators have reported their findings in terms of the amount of carotene present in the cabbage. Green cabbage contained more carotene than the white or purple cabbage tested. Munsell et al. (63, 64, 65, 66, 67, 68) reported carotene values for samples of cabbage from Central American countries as follows, expressed in milligrams per 100 grams: (a) Honduras, .038, .004, and .007; (b) Guatemala, .005, .059, .008 and for purple cabbage, .000; (c) El Salvador, .010 and .016; (d) Nicaragua, .004; (e) Costa Rica, .005, .021, and for purple cabbage, .016; (f) Guatemala, for purple cabbage, .016. The carotene concentration of fresh cabbage grown in Mexico was reported by Cravioto B. et al. (21) to be 0.14 milligram per 100 grams.

Wall and Kelley (101) used samples described as frozen savoy cabbage leaves and found an average value of 292.0 micrograms of carotene (alpha- and beta-carotene) per gram, dry basis. No data on a fresh weight basis were given. Pyke (83) found that the amount of carotene was higher in cabbage marketed early in its growth when the leaves were long and loosely headed than in the same variety marketed when fully matured into firm, blanched heads. Sheets et al. (89) reported 21 times as much carotene in green leaf blades as in blanched leaves.

Janes (40) stated that although the carotene content of cabbage is so low as to be of little importance from the standpoint of nutrition, analyses were made for several varieties of Florida-grown cabbage to find the range of values which might be expected. Dark Green Copenhagen grown at Hastings had the highest value, 0.264 milligram, but lower values, 0.120 and 0.112 milligram, were obtained at two other locations. For six other varieties tested, the range of values was from 0.044 to 0.160 milligram per 100 grams. The variation between locations for a particular variety reached 100 percent or more. French and Abbott (30) reported an average value of 176 micrograms for total carotene of cabbage grown in Florida. They found that the use of a supplement of minor elements with the major fertilizer applied to the soil at one location in Florida had little effect on the carotene level of the cabbage. Two lots of raw green cabbage used by Hewston et al. (36) were higher in carotene (0.314 and 0.440 milligram, dry basis) than the white cabbage (0.088). The fresh cabbage used by Krehl and Winters (45) contained 0.057 milligram, moist basis (0.83, dry basis).

Freshly cut shredded cabbage of Copenhagen variety contained 0.014 milligram of carotene and freshly minced cabbage of Charleston Wakefield variety had 0.012 milligram per 100 grams, according to Munsell et al. (62), who pointed out that the carotene content of cabbage is extremely low. Orent-Keiles et al. (77) reported average values of 0.290 milligram, dry basis, (range, 0.195 to 0.375) for shredded or for quartered and shredded cabbage used for coleslaw in an army mess. Other samples cut into pieces for boiling averaged 0.415 milligram (range, 0.235 to 0.685), dry basis. The cut cabbage at the time of serving as coleslaw had lost from 6.2 to 43.6 percent of the carotene. Munsell et al. (62) found both gains and losses during holding of coleslaw for serving on an institutional basis.

The effect of cooking on the carotene content of cabbage has been reported by several workers and the results show variations within rather wide limits. Hewston et al. (36) found average carotene retentions of 32.5, 62.2, and 67.6 percent, respectively, for three samples of cabbage during boiling by a home procedure. The cabbage of Krehl and Winters (45) prepared by four different methods of cookery had the following percentages of retention of carotene: boiled in water to cover, 73.3; boiled in a minimum of water, 89.7; in waterless cooker, 95.6; in pressure cooker, 96.8. Coward and Morgan (20) obtained a higher vitamin A value (9.6 International units per gram) for boiled cabbage than for the raw vegetable (8.8). Booher and Marsh (8) reported 170 International units of vitamin A value for pressure cooked summer cabbage in contrast to approximately 100 units before cooking. Orent-Keiles et al. (77) found changes during cooking and holding of cabbage for service in an army mess ranging from a loss of 29.8 percent of the carotene to a gain of 16.6 percent. Munsell et al. (62) tested cabbage cooked in large quantity and found 84 percent retention after boiling until done.

Hewston et al. (36) reported that extending the time of boiling to 60 minutes instead of 10 minutes had little effect on the proportion of carotene retained in the cooked drained cabbage. Munsell et al. (62) found a higher retention (97 percent) for cabbage boiled 2 hours on a large quantity basis than for the cabbage boiled 20 minutes (84 percent retention).

The use of a small amount of baking soda in the water, according to Coward and Morgan (20), had little effect on the vitamin A potency of boiled cabbage. Munsell et al. (62) found that holding of cooked cabbage to keep it warm for service resulted in a decrease in carotene retention from 84 percent after cooking to 69 percent at the time of serving.

Harris et al. (34) determined the vitamin E content of many different fruits and vegetables purchased in the open market. For cabbage, they reported 0.11 milligram of total tocopherols, fresh basis, of which the alpha form constituted 0.06 milligram and the gamma and delta forms together, 0.05 milligram. When expressed in relation to the weight of extracted lipid, the potency for total tocopherol was 0.7 milligram and for alpha tocopherol, 0.4 milligram per gram of lipid.

The vitamin K values reported by Dam and Schonheyder (23) for three kinds of cabbage, the samples of which were described as dried in air at 60°, were the following, in biological units per gram of dry

material: white, 230; red, 60; and "Spitzkohl," 240 units. Dam and Glavind (22) found 400 units per gram of dry material for green leaves of cabbage and 100 units for the inner leaves.

PALATABILITY OF RAW AND COOKED CABBAGE

There was a lack of agreement as to the superiority of one method of cooking cabbage in comparison with other methods. Data on judges' scores for several palatability factors by Sutherland et al. (94) indicated that open saucepan and pressure saucepan methods of cooking cabbage gave more satisfactory results than cooking in a tightly covered pan or in a steamer.

Even though steamed cabbage was found to contain more ascorbic acid than that cooked in water, Lampitt et al. (48, p. 65) stated that "changes in colour and flavour, normally regarded as deterioration, occur on steaming and this factor must not be forgotten when assessing the value of steam cooking." The appearance of steamed cabbage was said by Allen and Mapson (2) to be less attractive than that of boiled cabbage due to the development of an olive-green or brownish color and strong flavor in the steamed cabbage. On the other hand, Munsell et al. (62) in a study of large scale cookery methods stated that the steamed cabbage was superior to the boiled cabbage in appearance, taste, flavor, and texture.

When judged subjectively for color, flavor, texture, and odor, cabbage cooked in either the waterless cooker or in the pressure saucepan was rated inferior to that in the open kettle, according to Brinkman et al. (11). On the basis of a scoring system in which aroma, tenderness, flavor, and color were considered and a maximum of 80 points was allotted, Eheart and Sholes (26) reported the following scores for cabbage cooked by five different methods: in open kettle, 73.5; modified old-fashioned, 68.4; in tightly covered kettle, 68.0; fried, 62.5; old-fashioned, 51.3.

Palatability scores by Van Duyne et al. (98) obtained by adding the numerical values (score of 5 was maximum, 1 was minimum) for each of five different characteristics evaluated by judges (appearance, color, flavor, absence of off-flavor, and texture) revealed no significant differences in palatability of the cooked cabbage due to cooking in a tightly covered saucepan or in a pressure saucepan. Neither were palatability scores significantly different in two succeeding years, 1948 and 1949.

In evaluation of cabbage cooked by three methods, Patton et al. (78) found that cabbage boiled in sufficient water to just leave the vegetable dry at the end of the cooking period had the best color, the vegetable boiled in an excess of water had the best texture, and the panned cabbage had the best flavor. Considering several characteristics, the cabbage cooked in a small amount of water or by panning was superior to that cooked in excess water. Bollman et al. (6) reported that on a 10-point rating scale, average scores were 7.2 for cabbage cooked in an electronic range and for the vegetable boiled in water to cover. The pressure cooked samples were scored an average of 7.4. The workers explained that since vegtables have a tendency to form a tough outer skin during cooking in the electronic range, enough water to cover the vegetable was used and the cooking time was kept at a minimum in order to avoid the skin effect as much as possible. Even with this procedure the electronically cooked cabbage was described as crisp and undercooked. The color of the cabbage prepared in this manner was superior to that cooked in the pressure saucepan and similar to that of the boiled cabbage. No particular differences in flavor were noted.

In a comparison of palatability scores by Van Duyne et al. (98) for cabbage cooked until tender in a pressure saucepan and for similar samples overcooked by cooking for 1.5 minutes instead of 1 minute, the total scores for the five palatability characteristics were not significantly different for the two products.

SUMMARY OF FINDINGS

The following generalizations concerning factors influencing the vitamin values and palatability of cabbage are based on findings in the literature exclusive of the work done as a part of the National Cooperative Project.

Raw cabbage was found to be a good source of ascorbic acid and a high proportion of the vitamin was present in the reduced form. Varieties and strains of cabbage differed in the amount of ascorbic acid they contained. The lowest average value noted for a specific variety was 7 milligrams per 100 grams and the highest was 180.9 milligrams. Red and purple varieties were generally found to be rich in ascorbic acid. Particular varieties and strains of cabbage differed in ascorbic acid content from year to year and for various locations in which grown, but the relative level for a variety had a tendency to be maintained through heredity.

With but few exceptions, the season in which cabbage was grown affected the ascorbic acid content. Plants harvested in the spring and early summer were generally richer in ascorbic acid than those harvested in other seasons of the year. Limited data on the effects of irrigation indicated either no difference or a decrease in amount of ascorbic acid with increased frequency of irrigation. Fertilizer applied to the soil had little or no effect on the amount of ascorbic acid in cabbage. As the cabbage plant matured, there was a decline in ascorbic acid content of the tissue.

Ascorbic acid was unevenly distributed within the head. Green leaves contained more vitamin C than bleached leaves. The core and the outer leaves were richer in ascorbic acid than the parts of the plant generally used at the table. Small heads, in general, contained more ascorbic acid for each unit of weight than large heads. Losses of vitamin C during storage were found to increase with rising temperatures and with increasing lengths of time of storage.

Ascorbic acid losses of varying severity occurred during the cutting of cabbage and the trend was toward greater losses as the amount of bruising of tissue was increased. The temperature at which cut cabbage was held was an important factor in vitamin C stability. The use of low temperatures favored the retention of vitamin C in the cabbage. The presence of mayonnaise or of French dressing on cut cabbage during holding for a few hours had a slight protective action on ascorbic acid.

For the cooking of cabbage, the use of a tightly covered utensil with a small amount of cooking water resulted in a higher retention of ascorbic acid than with open pan cookery. Utensils in which steam rather than water was in contact with the cabbage were conservative of ascorbic acid. The principal loss of vitamin C was by solution into the cooking water rather than by destruction. In comparing the effects of different amounts of water for boiling cabbage, the tendency was for increased loss of ascorbic acid to occur as the quantity of water was increased.

A study in which various pressures were used for cooking in a pressure saucepan indicated no relationship between destruction of ascorbic acid and the temperature maintained in the utensil. Experiments for boiled cabbage in which the vegetable was added so slowly that the water continued boiling gave slightly better retention than when the vegetable was added all at once. For cabbage placed in a steamer before the water boiled, reports showed either no difference or greater loss of ascorbic acid than in the cabbage added after the boiling point was reached.

Large pieces retained more ascorbic acid during cooking than small pieces of cabbage. With some exceptions, decreased retentions of ascorbic acid were found as the cooking periods were extended beyond the time necessary to reach the done stage. No clear-cut effect of the addition of table salt on ascorbic acid content of cooked cabbage was found. Limited data indicated only slight or no losses of ascorbic acid associated with the use of small amounts of soda in the cooking water for cabbage.

Losses of ascorbic acid occurred during holding of cooked cabbage at refrigerator temperatures and as the cabbage was held by various means to keep it hot for serving. The ascorbic acid values for cooked cabbage as served were generally much lower than the original values for the raw cabbage.

The content of thiamine, riboflavin, niacin, carotene, and other vitamins or provitamins was found to be low in comparison with the amount of ascorbic acid in cabbage. For the data presented on a fresh weight basis, the average values ranged from 25 to 142 micrograms per 100 grams for thiamine, 25 to 85 micrograms for riboflavin, 118 to 526 micrograms for niacin, and 0 to approximately 500 micrograms for carotene (or vitamin A value). Limited data were presented on the concentrations of other vitamins or provitamins in cabbage.

Somewhat greater stability during storage, cutting, cooking, and holding was shown for the other vitamins than for ascorbic acid. The factors affecting the retention of these nutrients were, in general, those which determined the amount of ascorbic acid in cabbage as eaten.

In regard to palatability, there appeared to be no particular cooking method which consistently gave superior results by all workers and for all palatability factors, such as aroma, color, texture, and flavor of the cabbage. In general, the use of an open pan, a tightly covered pan, or a pressure saucepan for household cooking gave more palatable cabbage than the steamer or the waterless cooker. In limited data on large quantity cookery steamed cabbage was rated superior to boiled cabbage. Electronic cooking tended to produce a product that was tough or crisp and underdone.

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APPENDIX

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DEHYDRATED CABBAGE

Vitamin Values and Palatability

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